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STUDY TO ANALYZE THE ACQUISITION OF AUTOMATIC TEST EQUIPMENT (ATE) SYSTEMS. DATA SEQUENCE NUMBER A003

RCA/Government and Commercial Systems

Prepared for:

Naval Electronics Laboratory Center

27 December 1973

RCA

FINAL REPORT

FOR

# STUDY TO ANALYZE THE ACQUISITION OF AUTOMATIC TEST EQUIPMENT (ATE) SYSTEMS

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RCA/GOVERNMENT AND COMMERCIAL SYSTEMS
AEROSPACE SYSTEMS DIVISION
BURLINGTON, MASSACHUSETTS 01803

U.S. NAVAL ELECTRONICS LABORATORY CENTER
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Unclassified

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Approved
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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

## LIST OF ILLUSTRATIONS

## LIST OF ILLUSTRATIONS (Cont.)

## ABSTRACT

The Hughes Aircraft Corporation and the RCA Corporation were assigned complementary tasks by the Naval Electronics Laboratory Center under two separate contracts for studies to analyze the acquisition of automatic test equipment (ATE) systems. It is NELC's intent to integrate into a single document the separate final study reports required to be submitted by each company. Toward that end, NELC issued a combined outline, and tasks were assigned to each company within that framework. This report represents only the results of the RCA effort. However, as an aid to visualizing the RCA tasks within the total context, the table of contents and the body of the report are annotated to indicate the sections which were assigned to Hughes.

# SECTION 1

# INTRODUCTION[1]

## 1.1 GENERAL

The potential logistic advantages of automatic test equipment (ATE) are well understood. This study has identified program management approaches and procedures toward achieving those advantages, with particular stress on the need for timeliness in making ATE decisions and on the organization of technical and management forces to implement the decision process. The selection of automatic test equipment is properly a part of logistic planning; therefore, the results of the study are keyed to the prime equipment acquisition phases defined in NAVMAT INST 4000.20A, titled "Integrated Logistic Support Planning Policy".[2]

Some of the information presented herein is already well known to ATE experts; some of it will be familiar to logisticians, and other portions will be obvious to program managers. However, this is the first time that all of this information has been brought together for the guidance of SYSCOMS in the future selection of ATE - a process which requires the carefully timed cooperation of technical, logistic, and management personnel.

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[1] Hughes Aircraft Corporation inputs were integrated by RCA into this combined section, per agreement at NELC review meeting, 73 Nov. 14.

[2] It is recommended that the procedural portions of this report should be condensed to approximately 5 pages and prepared in a format which will be acceptable to the custodian of NAVMAT INST 4000.20A as an appendix to that instruction.

Figure 1-1 diagrams the technical, logistic, and management interdisciplinary relationships for the purpose of showing how ATE selection fits in with the overall prime system definition. The first step is a technical definition of the prime equipment to be supported, based on operational mission requirements. This information is needed by logisticians to enable them to develop support concepts, including spares and repair level policies upon which ATE may impinge. The same information enables the test equipment engineer to develop test requirements upon which his ATE recommendations will eventually be

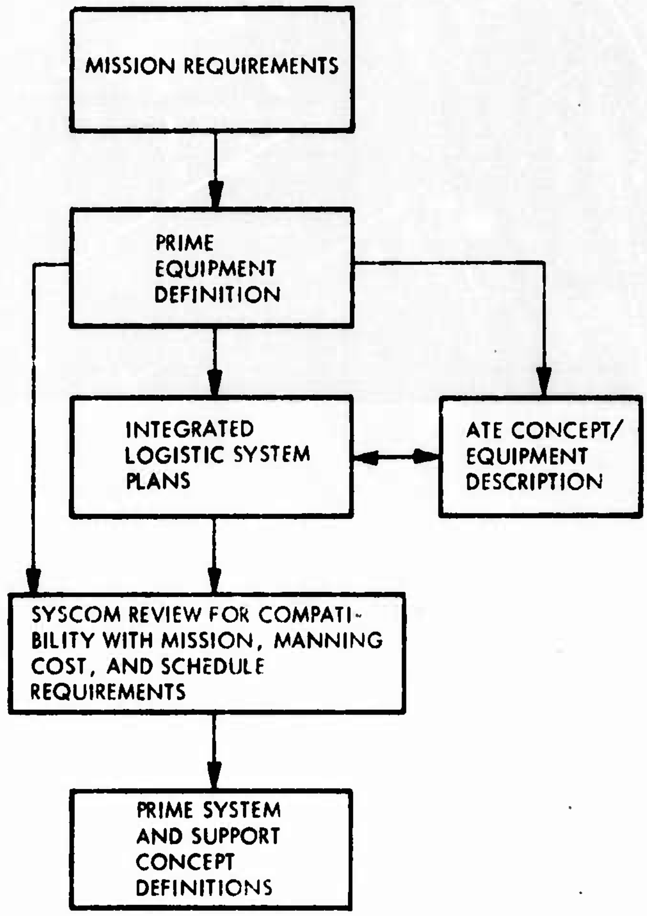


Figure 1-1. Interdisciplinary Relationships of ATE Selection

based. A double-headed arrow between logistic plans and ATE concept/equipment description denotes the iterative nature of test equipment selection, whereby initial logistic goals may be modified by later evaluation of test equipment capabilities.[1] The prime equipment definition and the logistic plans, which would include ATE recommendations, would then be reviewed by the SYSCOM and modified if necessary for compatibility with mission, manning, cost, and schedule requirements. Finally, a combined prime system and support concept would be defined by the SYSCOM. This same general procedure is followed at every phase of the prime equipment acquisition process, except that the ILS concept and the ATE can be defined in increasing detail as the prime equipment design matures with each subsequent phase. Five phases of prime equipment development, as defined in Appendix H of NAVMAT INST 4000.20A, are used to determine the various events and decision points of the ATE development cycle. These are:

(1) Conceptual Phase

(2) Validation Phase (Engineering and Development)

(3) Full Scale Development Phase (Operational System Development)

(4) Production Phase

(5) Deployment/Operational Phase (Logistic Support, Inventory Control, Training, etc.)

During the Conceptual Phase, the prime equipment is defined basically by needs and objectives. Very general support requirements are specified, such as

[1] Although this study is devoted entirely to automatic test equipment, it is recognized that manual test equipment may be an attractive alternative for certain limited applications.

desired (or required) operational availability. Comprehensive system studies are performed.

During the Validation Phase, the major program characteristics are validated. This phase ends with the contract to proceed with the detail design. Support alternatives, including off-line vs on-line, are considered and general requirements for support equipment are resolved. Logistic support models which consider system life cycle cost are applicable to this phase.

During the Full Scale Development Phase the prime equipment design is completed, and the support equipment is defined and prototyped.

During the Production Phase off-line test equipment specifications are completed and procurements initiated.

During the Deployment/Operational Phase, prime equipment specifications are generally frozen, and if new test equipment procurements are made, they must be tailored to the existing prime equipment.

## 1.2 IMPACT OF ACQUISITION PHASES

For homogeneous equipment or systems, defined as those in which all components are at a similar stage of development, the ATE/ILS iterative relationship is essentially as shown in Figure 1-2, which is an expansion of the ATE/ILS portion of Figure 1-1. The process starts with the initial proposal of an ILS concept, which will include, among other things, availability, manning budgets, and the repair policy at each maintenance echelon. From these parameters, ATE alternatives toward meeting ILS goals can be defined, and then comparatively evaluated to establish benefit/cost ratios. As a result of this evaluation it may

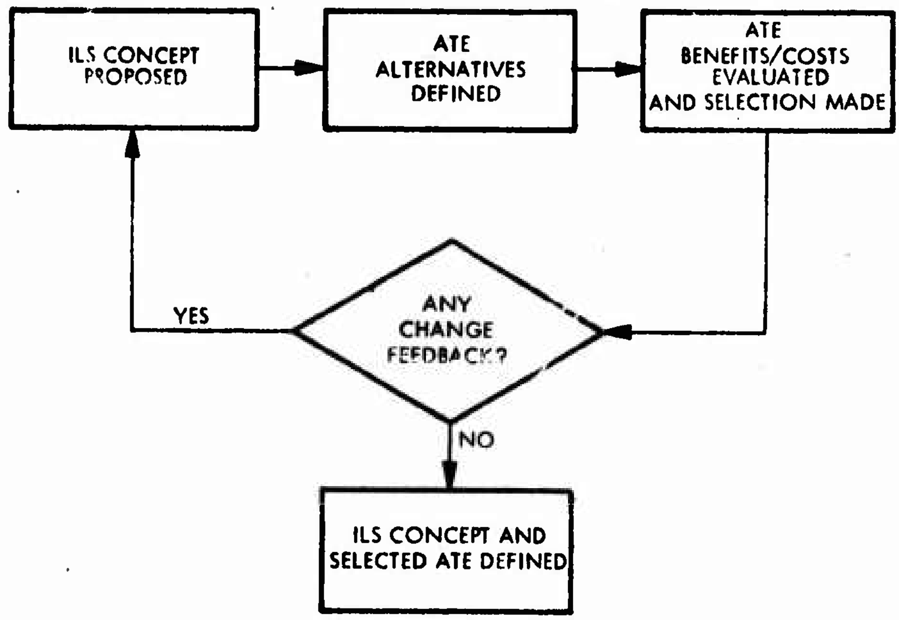


Figure 1-2. Interrelationship of ILS and ATE

prove necessary to feed changes back into the initial ILS concept, where the ILS concept may have been either too ambitious or not demanding enough. For example a module tester may be available or producible at a low enough cost to make it economical to change a logistic policy from one which originally called for module repair at depot to a policy of module repair on shipboard, with a saving in shipboard spares and eliminations of depot pipeline delays.

For ships, aircraft, and other systems which are heterogeneous in that they utilize items in various stages of development, the process shown in Figure 1-2 becomes operative at more than one equipment or indenture level (e.g. component, module, assembly, etc.) for each maintenance echelon. Figure 1-3 summarizes the essentials of the test equipment selection process for such a system, consisting of a combination of existing equipment, equipment currently in development,

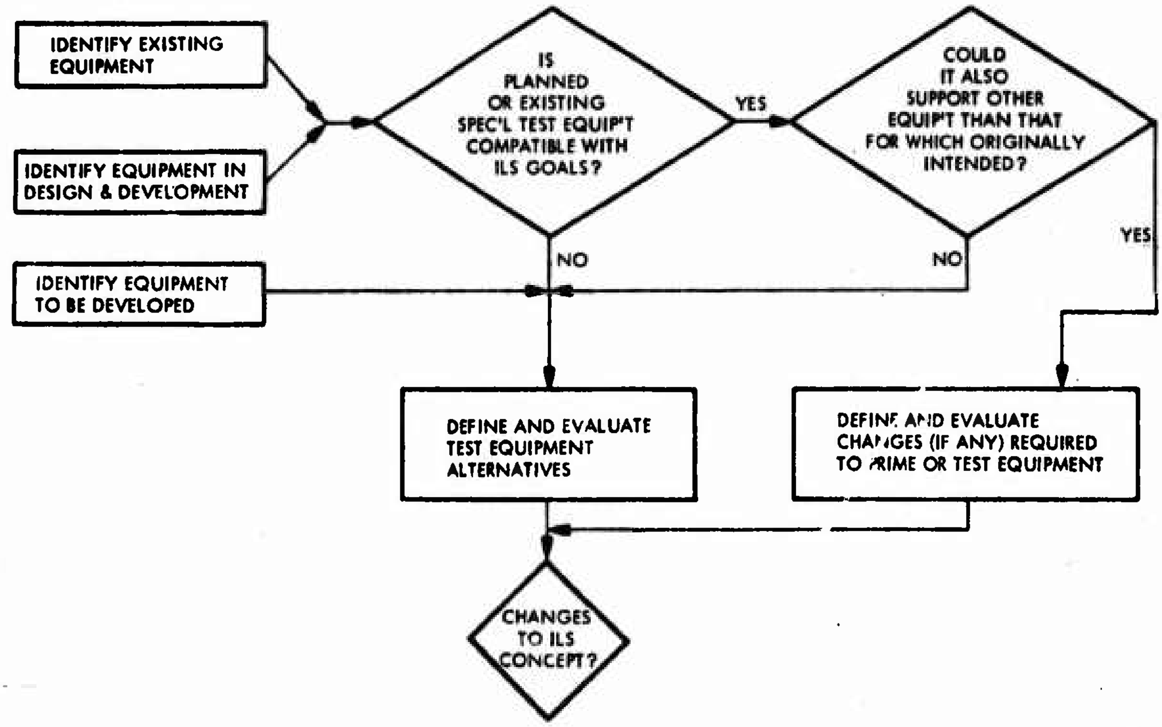


**Figure 1-3. Impact of Mixed Acquisition Phases**

and equipment still in the concept phase. For prime equipment in the first two categories, planned and existing special test equipment must be reviewed for compatibility with the proposed ILS concept. If not compatible, then other test equipment alternatives must be examined, and either another alternative selected, or the ILS concept altered. For heterogeneous systems, it may be necessary to accept compromises which result in a non-uniform level of repair, so that at the organizational echelon, for example, some equipments may be repairable by assembly replacement, some by module, and others by component replacement. Test methods and maintenance procedures might be compromised instead, in order to preserve a uniform repair policy, in which case ATE and manual test methods plus a mix of different maintenance skill levels might be employed to accommodate the required degree of fault diagnosis.

If test equipment originally intended for prime equipment already in existence or in development is compatible with the planned ILS concept, then that same test equipment should be analyzed to determine whether it can also service other equipments in the ship, aircraft, or overall prime system, and, if so, whether modifications are required for that purpose. It is obvious that equipment not yet in development affords the SYSCOM a full range of ATE options, while for equipment further along, hard choices may be indicated between costly modifications to meet ILS goals, and compromising those goals. Since the available ATE options rapidly diminish as equipment leaves the Validation Phase, it is clear that the maximum benefits of ATE can best be realized through planning which starts with formulation of the program concept. Timeliness is especially critical when planning for built-in or other on-line test equipment configurations which require that anywhere from a portion to all of the test equipment will be an integral part of the prime equipment. Clearly, deferring the decision to use built-in or on-line test until prime equipment design is under way entails the risk of a costly design change.

The selection of off-line test equipment can be deferred to the Production or even to the Development/Operational Phase with the potential risk limited to obtaining less than optimum test performance where the designer has not been required to optimize test point accessibility for use with ATE.

## 1.3 SKILLS REQUIRED FOR ATE SELECTION

The need for ATE decisions to be made early in an acquisition program can only be satisfied by a technical team which contains a mix of prime equipment and ATE skills. The prime system is not normally defined in sufficient detail during the Validation Phase to facilitate ATE selection, except where exising equipment is being used. The team must be capable, then, of synthesizing the

proposed system in the detail required to enable test requirements to be analyzed. The ATE part of the team must be experienced enough to apply judgment to fit the inevitable gaps that will appear in the prime equipment test requirements definition during early acquisition phases. Logisticians are needed to ensure that ILS goals are met, and the whole must be under the direction of the SYSCOM to maintain program integrity.

## 1.4 PROCEDURE SUMMARY

The ATE selection procedure can be simply summarized in the following steps:

(1) Determine Test Requirements

This step requires knowledge of the prime equipment configuration and its logistic support policies.

(2) Identify ATE Candidates

Locate ATEs in existing inventory which will meet test requirements. If necessary, postulate new ATE for this purpose.

(3) Evaluate Candidates

Compare candidates on basis of technical performance, logistics, cost, and other predetermined evaluation criteria.

(4) Select the Optimum Candidate

The ATE selected will provide the optimum match to requirements.

## 1.5 ORGANIZATION OF THE REPORT

Section 2 describes ATE selection decisions as they relate to the various acquisition phases. Section 3 describes the ATE decision process relative to maintenance levels, and also contains a discussion of typical built-in test approaches since this is an area of increasing interest and application. Section 4 covers specifics of the steps in the ATE selection procedure, and because modeling can be a useful tool in ATE selection, a subsection discusses types and capabilities of logistic-related models. Section 5 contains examples of actual systems which have utilized ATE and describes the process by which the particular ATE type was chosen. Section 6 contains appendices which define ATE selection evaluation factors, a check list of items to be considered in ATE selection, a glossary of ATE-related terms, and a comprehensive discussion of data banks[1] and their applicability to the ATE selection process.

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[1] This outline is a preliminary one intended by NELC as a means of coordinating the work of the two contractors. However, the results of the data bank task (by Hughes Aircraft) are so extensive that it is considered likely that they will constitute a separate document when NELC integrates the RCA and Hughes reports.

## SECTION 2

## SUPPORT DECISIONS RELATED TO PRIME EQUIPMENT DEVELOPMENT CYCLE

### 2.1 ON-LINE VS. OFF-LINE[1]

Section 6.3 contains definitions which should eliminate the confusion often generated by the proliferation of redundant and conflicting automatic test equipment terms. The most misunderstood terms are on-line and off-line, and because of their relevance to the following discussion, a further attempt will be made to clarify their meanings. The on-line/off-line confusion arises because those terms are used to describe test equipment placement as well as operational mode, and the two are not necessarily consistent. Built-in test equipment (BITE) is defined as on-line because it is inherently connected to the equipment it supports. However, some of the tests performed by BITE may require interrupting normal operation of the prime equipment — that is, taking the prime equipment "off-line." BITE, then, although an on-line equipment in the sense of location or placement, can and usually does operate both in on-line and off-line test modes.

A simple digital voltmeter normally stored on a laboratory shelf is off-line test equipment in the placement sense. It can be temporarily connected to an equipment to perform on-line or off-line tests, depending on whether the tests are operationally non-interfering or interfering, respectively. Permanently wired

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[1] This subsection was not in the original NELC outline. Its addition moved subsequent sections up by .1.

into a prime equipment, it becomes on-line equipment, regardless of test mode. The AN/SSM-5 (TEAMS) and the AEGIS MK 545 ORTS are centralized test systems which are dedicated to, or always connected to, the equipment they support. Therefore, they are classified as on-line equipments, even though, unlike BITE, they can be disconnected or removed from the prime equipment without disassembling or disabling the prime equipment, and even though some of the tests they perform require taking the prime equipment off-line.

In summary, based on clarifying discussions with Navy engineering personnel, these are the definitions of on-line and off-line as the terms will be used in this report. ON-LINE TEST EQUIPMENT is test equipment which is dedicated and permanently connected to the prime equipment, regardless of whether the test equipment is built-in or separate from the prime equipment. OFF-LINE TEST EQUIPMENT is test equipment which is not installed as part of, or permanently connected to, the prime equipment. ON-LINE TESTING is testing which can be performed while the test equipment is in operational use, and without interfering with its operation. It may be performed by on-line or off-line test equipment. OFF-LINE TESTING is testing which necessitates interruption of, or interference with, prime equipment normal operation. It, too, may be performed by on-line or off-line test equipment.

## 2.2 CONCEPTUAL PHASE

### 2.2.1 Introduction

The confidence with which test equipment decisions can be made depends almost entirely on the information available for the equipment to be supported. Obviously, the supported equipment will be least well defined during the Conceptual Phase,

and only late in the Validation Phase can modules and their detailed test requirements be identified. Nevertheless, basic test equipment decisions do need to be made during the Conceptual Phase, and it is clear that the decision process will require considerable judgment and experience in the absence of firm and detailed technical information during that phase. The decision to use built-in test equipment (defined here as test equipment which is an integral part of the prime equipment) must be made during the Conceptual Phase.

Deferring that decision to a later phase is inviting a costly design change in the prime equipment at that time. Somewhat less urgent is the decision to use external test equipment. Even in this case, however, there are reasons for making that decision during the Conceptual Phase. The possible need for test equipment interface hardware within the prime equipment is one such reason. And even if no integral interface equipment is required, if the test equipment or test method can be specified before validation, the design can better provide for the necessary test access. While the foregoing statements can generally be applied to mechanical as well as electronic equipment, test decisions for mechanical equipment which will need relatively few sensors for test purposes could be deferred to the Validation Phase with a lesser risk of major design changes. An example of mechanical equipment for which test decisions should be made during Conceptual is a gas turbine engine. A larger number of sensors must be planned for than are needed for normal operational instrumentation, particularly if gas path analysis is selected as the means for evaluating engine performance.

Figure 2-1 summarizes the types of ATE decision that can be made during the Conceptual Phase, and the format for defining those decisions. The decision as to whether to use on-line, off-line, or both classes of test equipment is

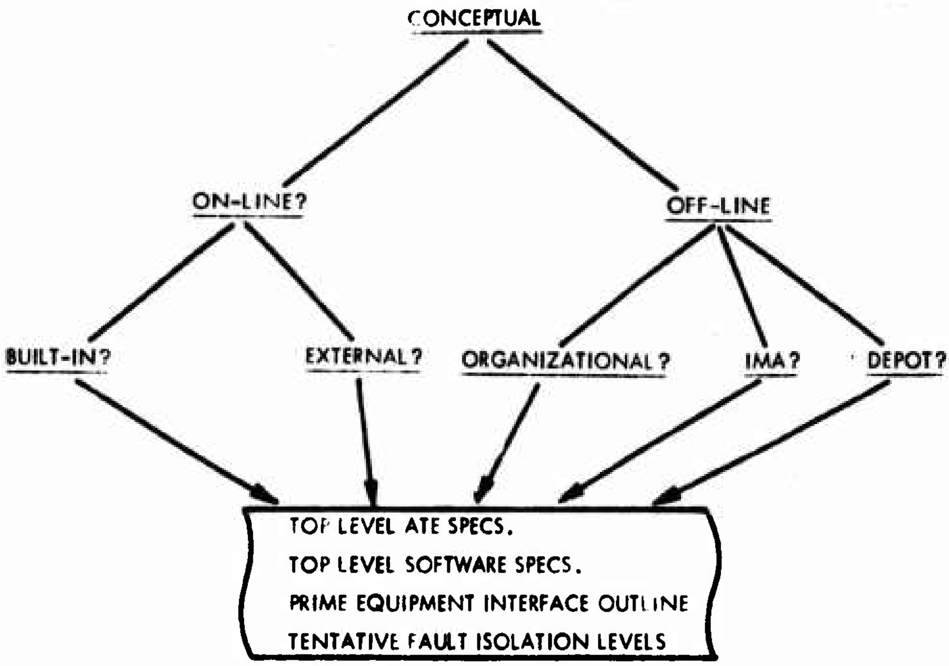



Figure 2-1. Conceptual Phase ATE Decisions

made during this period. Also, whether the on-line equipment should be built-in or external should be defined, along with the maintenance level at which off-line test equipment will be used. The results of these decisions are summarized in top level specifications for the ATE hardware and software. Impact on the prime equipment anticipated from the ATE interface will be defined in a general way, as will the fault isolation level for on-line equipment. It will be possible to be more specific about the fault isolation level for off-line test equipment, because off-line test equipment is usually not hampered by the stimulus, space, operational non-interference, and other considerations which limit the fault isolation capability of on-line test equipment.

## 2.2.2 Meeting Availability Goals

Availability of the prime equipment will be specified to be consistent with mission requirements. Availability $= \frac{MTBF}{MTBF + MTTR}$. Improving MTBF in order

to increase availability is not a function of test equipment selection, but is determined by prime equipment complexity and component state of art. However, MTTR and thus availability, can be improved by the selection of test equipment which will reduce the portion of repair time required for diagnosis of the faulty component or assembly, and for retest after repair. Where availability goals are difficult to meet, consideration should be given to the use of on-line test equipment in order to minimize diagnostic time. The designer has the choice of specifying built-in test equipment or an external test set which is always connected to the prime equipment. In either case, since diagnostic time is only a portion of MTTR, the prime equipment must be designed to minimize access time for parts replacement. Also, the test equipment availability should exceed that of the prime equipment (ideally, 10 to 1), and similar design practices should be applied to achieve that goal. With on-line test equipment complexity usually less than 10 - 15 percent of the prime, a higher MTBF than the prime is assured at least on a parts count basis, but self-test is still necessary to sense test equipment failures which can cause false goes and no-goes in the test results, and to minimize the test equipment MTTR.

### 2.2.3 The Role of the Maintenance Engineering Analysis (MEA)

The MEA is initially made during the Conceptual Phase. It will necessarily be incomplete at that point because of the lack of technical detail which can be made available. The MEA is therefore updated through subsequent prime equipment acquisition phases. Maintenance Engineering Analysis (MEA) forms are usually used to specify test equipment requirements and thus are normally not useful as raw inputs to an ATE selection process. However, where logistic funding permits, and often this is only the case on major weapon system procurements, the MEA process can be expanded during validation to specify

detailed test requirements at the stimulus and measurement level for each module, thereby enabling test equipment selection to be made with a high degree of confidence.

During the Conceptual Phase, the MEA can only assist in making broad test decisions, such as, for example, whether an on-line or off-line test equipment approach should be chosen to meet availability requirements, and selecting the equipment level to which fault isolation should function.

## 2.3 VALIDATION PHASE

During the Validation Phase, detailed design decisions can be made for test equipment options previously selected during Conceptual. To decide to incorporate built-in test after validation has been contracted for could result in costly design changes. However, the final selection of off-line test equipment could be made as technical details of the prime equipment unfold to enable a fine-grain analysis of test requirements to be made — possibly via the MEA procedure. This is the phase during which a module tester could be selected. Figure 2-2 summarizes the ATE decisions of the Validation Phase, which are largely those which expand in detail on major decisions previously made. Results consist of detailed ATE hardware and software specifications, and either selection of existing test equipment, or specification and start of design for new test equipment. Details of the prime equipment interface will be developed as the prime equipment design becomes better defined. The functioning and specifics of fault isolation will also become definable, with particular impact on on-line test equipment. At this stage the need for compromises on on-line performance will become apparent, and it may be found that "fault isolation to the module level" may in some instances have to mean fault isolation to a group of modules rather than always to an individual module. Packaging

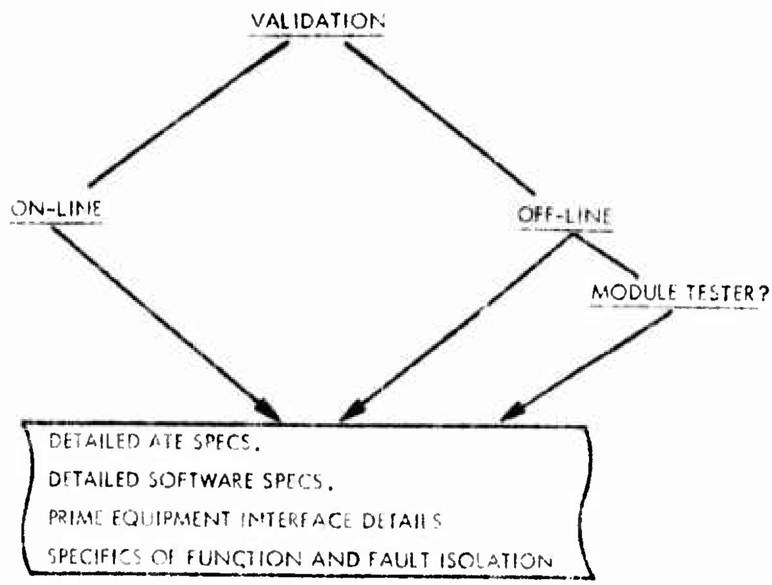



Figure 2-2. Validation Phase ATE Decisions

and circuit partitioning of the prime equipment form one of the major constraints on the fault isolation capability of on-line test equipment. Maximizing packaging efficiency and standardization leads to the design of modules containing many identical circuit elements, such as all flip-flops or all gates, to be distributed over a number of subsystem functions. The many input and output lines of these modules make them difficult to fault isolate with on-line test equipment. Inevitably, compromises between prime and test equipment design goals will be necessary, and these are best resolved where the same engineering management directs the prime and the on-line test equipment design tasks.

## 2.4 PRODUCTION PHASE - HUGHES AIRCRAFT CORPORATION

## 2.5 DEPLOYMENT/OPERATIONAL PHASE - HUGHES AIRCRAFT CORPORATION

# SECTION 3

# SUPPORT ALTERNATIVES BY MAINTENANCE LEVEL

## 3.1 ORGANIZATIONAL

The selection of support alternatives for the organizational level requires critical technical decisions to be made early in the acquisition program before technical details have been developed. Organizational test equipment is more tightly bound by physical, cost, and manpower constraints than is test equipment intended for other maintenance levels. On-line test equipment, whether built-in or external, is a strong contender at this level, and the added cost per installation multiplied by the number of installations requires consideration of MTTR reducing methods which do not rely entirely on test equipment. Figure 3-1 illustrates the range of generally acceptable BITE complexity expressed as a percentage of the prime equipment. Two percent is the approximate minimum, although it could run lower for a simple detector to indicate the presence of power. More significant is the maximum, which is set at 10-15 percent to ensure an MTBF significantly higher than the prime equipment, and to avoid an intolerable increase in acquisition cost. Where BITE may require a greater percentage of the prime, self-healing and adaptive circuitry become serious contenders, although as will be discussed, these methods can be costly and do not necessarily eliminate the need for organizational test equipment.

Design approaches will be briefly discussed in this section which can replace or augment organizational test equipment.

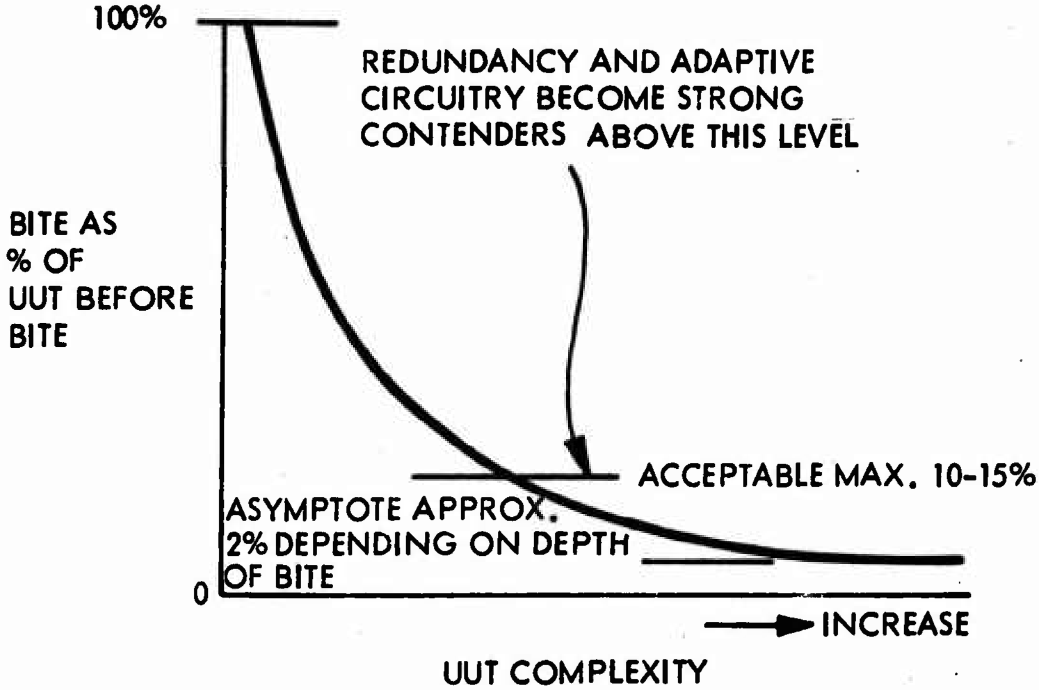


Figure 3-1. BITE Relative to the UUT

### 3.1.1 Built-in Self-Healing

Built-in self-healing is a design technique which can reduce and perhaps eliminate built-in test equipment. It is beyond the scope of this report to attempt detailed coverage of this technique. However, it is discussed here because it must be considered as an alternative to built-in test equipment. Active self-healing would detect the presence of a fault and automatically switch over to a standby circuit. Since active self-healing must contain a fault-detection mechanism, it can provide a BITE function by externally displaying the malfunction detected.

Passive self-healing is achieved by redundant circuitry which automatically assumes the function that was performed by a failed component, without the need for fault detection. Figure 3-2 illustrates the technique as applied to a simple diode path. Here four diodes are connected in what is sometimes known as a "hammock" circuit. It can be seen that a normal diode path will continue to

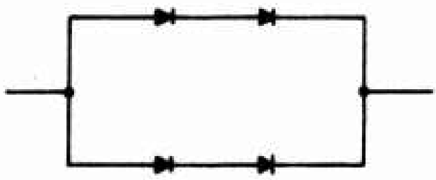



Figure 3-2. Component Redundancy

exist for a variety of combined failures. Figure 3-3 shows two dc power supplies isolated from each other by diodes but feeding the same load. If both supplies provide the same output voltage they will equally share the load. If one goes down, the survivor will supply the entire load. Each supply would have to be capable of handling the entire load. The degree of redundancy can be increased to improve operational reliability, but, clearly, at a further increase in cost and complexity. The danger in passive self-healing is that there is no way of knowing whether or not the equipment is working on its last reserve component or assembly. Auxiliary BITE devices would be needed to detect a failure of

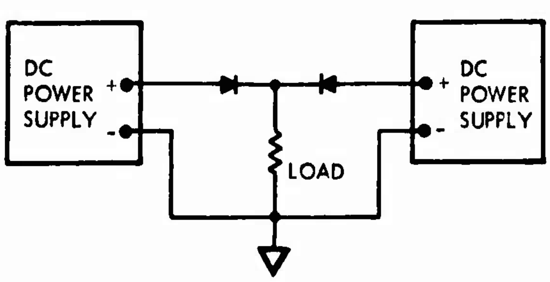



Figure 3-3. Assembly Redundancy

one of the power supplies in figure 3-3. However, detecting failures in redundant components, such as the diodes of figure 3-2, would not be as straightforward. To avoid the need to probe the diodes individually, precise voltage readings across the entire network would be needed, with the network replaceable as one unit. Simple examples have been presented here. Much more complex variations of self-healing will be apparent to designers of digital equipment. However, the problem of detecting failures when the entire system continues to operate normally remains a serious one.

Voting circuits are another form of self-healing, and they may or may not contain an inherent failure detection mechanism. Figure 3-4 is an example of

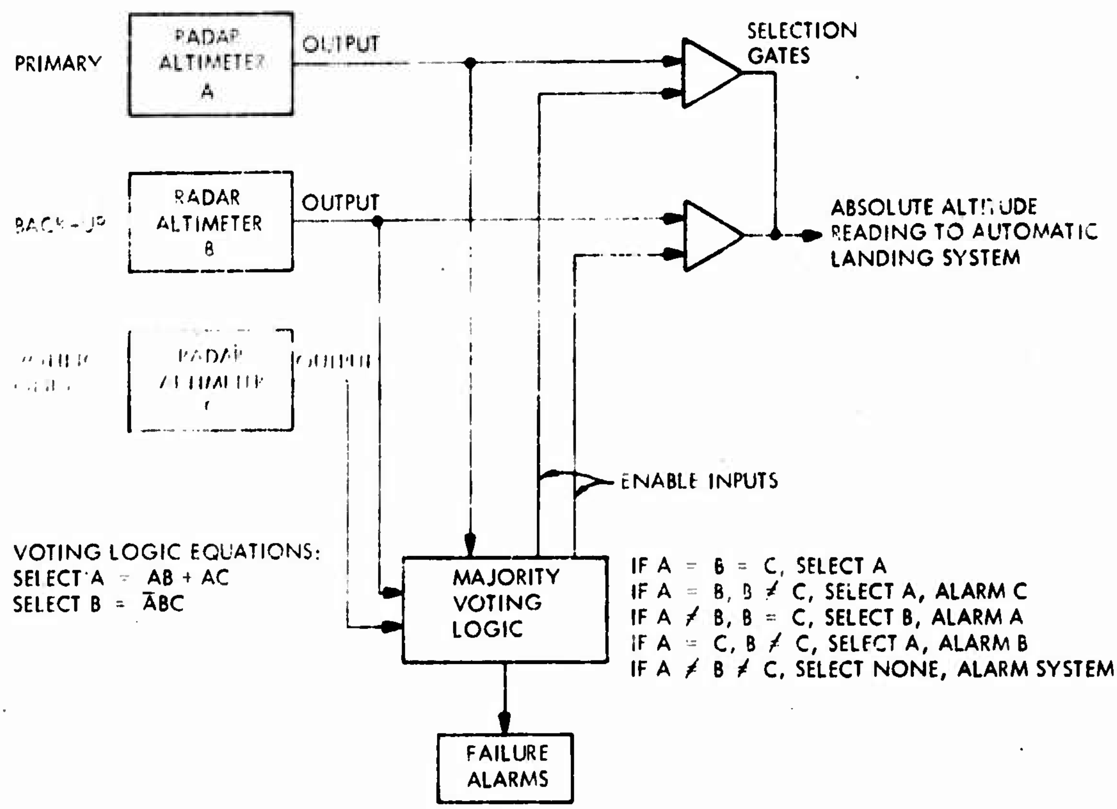



Figure 3-4. Voting Logic Application

voting logic dictated by flight safety considerations. Shown is a method for using three radar altimeters in an automatic landing system.

Altimeter A is the primary altimeter, and its output will be used if it is in agreement with either B or C. Altimeter B is the backup to A, and C is used only for voting purposes. This is a simplified example. Obviously, a threshhold of agreement would need to be established, and also the logic would have to recognize "agreement" due to two or more sets being turned off.

### 3.1.2 BITE On-Line Fault Isolation to the Replaceable Module

The ideal in ATE operation is to fault isolate to the replaceable module level, using built-in test equipment (BITE), while the prime system is on-line (operational). To achieve this goal requires either that normal operation provide the necessary stimulus, or that it can be applied by the BITE without interfering with the module's normal functioning. Oscillator, clock, and power supply modules are self-stimulating and can be fault-isolated by output measurement. Amplifiers through which a signal of known characteristics flows during normal operation can also be fault-isolated on-line by simple measurement. Pulsed oscillators or generators where the measurement can be synchronized with the trigger also lend themselves to on-line fault isolation. Mechanical devices are often naturally self-stimulating. Pressure systems, engines and other rotating machinery are fault isolatable on-line with a much lower sensor or test point density than is usually encountered with electronic equipment. Radio and radar receiver modules present special problems because the wide range of normally encountered signal types and intensities are too unpredictable to be suitable as test stimuli. Modules of a radar receiver, however, could be externally stimulated by BITE during the transmission part of the radar cycle, although that would not be on-line testing in the purest sense of the term. Digital modules

can be fault-isolated on-line, similarly to the case of the radar receiver, by stimulating them and measuring response between operational windows. This is, in effect, a time-sharing technique, where test modules in the operating software feed test patterns and evaluate response between normal computational pulses.

As mentioned previously, packaging efficiency and standardization are often the enemies of on-line fault isolation, because they tend to complicate the stimulus and test logic required to fault isolate to a single module. The ideal module for fault isolation is one with a single input and output. If a module contains an IF amplifier along with stray components from other functions for which space happened to be available on the IF module, then fault-isolating the module will obviously be considerably complicated by the need to test the sub-functions or sub-sub-functions represented by the odd components. Digital modules are often standardized for good logistic reasons. But where a standard module can contain dozens of identical logic gates for external connection to many logic circuits, there is an obvious problem in isolating failures to that module, and the continuing development of computer programs for automatic generation of digital test patterns represents the most likely solution to the problem.

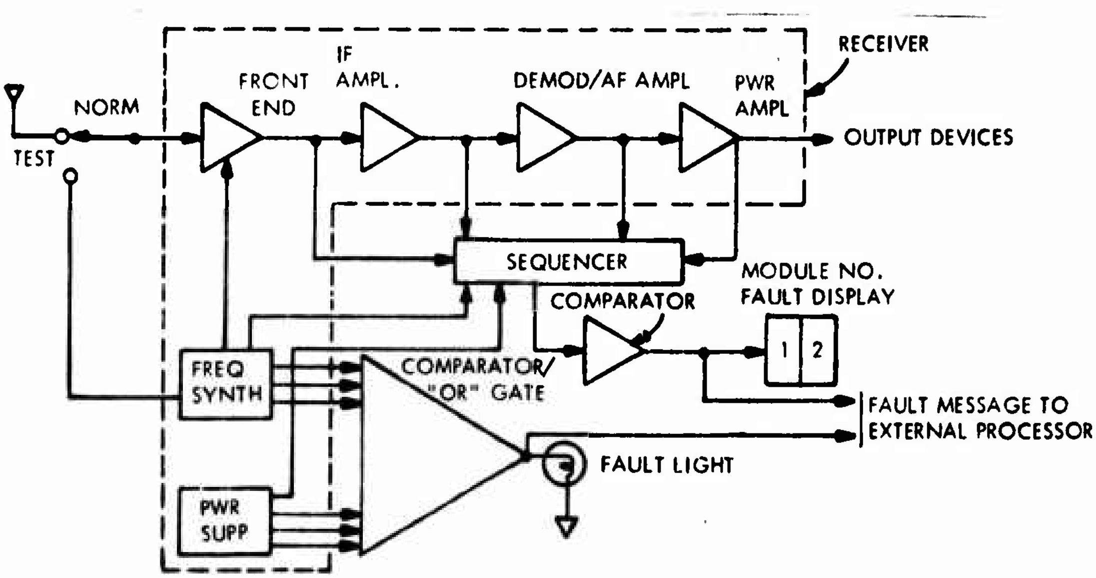
Regardless of whether fault-isolation is to be accomplished on-line or off-line, its achievement requires a team effort involving the circuit design engineer, the packaging engineer, and the test engineer. Circuit partitioning is the most important factor in the success of BITE.

### 3.1.3 BITE Off-Line Testing to the Replaceable Module

With the inhibition of operational non-interference removed, it becomes considerably simpler to isolate faults to a replaceable module with BITE. However, the practical limitations on space for stimulus generators and access to input terminals keeps BITE from achieving the test capability of off-line (external) test equipment. In the future, microcircuit developments should alleviate the problem and increase the application of BITE techniques.

Figure 3-5 is a simplified diagram of a BITE approach developed for a communication transceiver which achieves fault isolation to the replaceable module, using a combination of on-line and off-line test techniques. Only the receiver portion is shown to illustrate the technique as it is applied by RCA to the Mk LC HF Transceiver, a successor to the AN/ARC-161 HF Transceiver which is too new to have been assigned an AN/ARC-number. Frequency generator modules of the frequency synthesizer, and power supply modules are basically self-stimulating, so they are continuously monitored on-line, and a single fault light indicates failure of any one of those modules, while a numerical readout indicates the particular faulty module. If it is desired to run a routine check, the operator presses a button and briefly interrupts normal operation to initiate a complete self-test. A signal generated within the frequency synthesizer is switched to the antenna terminal in place of the antenna, and an automatic sequencer steps through each module in turn, starting at the front end and proceeding toward the audio output, while testing for module failure by evaluating the signal at each inter-module junction. When a failure is detected, the sequence stops and an indicator displays the number of the module to be replaced. The success of this method resulted from a coordinated design effort whereby circuit partitioning and packaging were directed toward the goal of completely automatic built-in module fault-isolation. The percentage increase in system

complexity through the use of BITE was well under five percent in this case, thanks to the ingenious minimization of stimulus. The only drawback in this approach would seem to be that, in case of multiple failures, only one faulty module at a time could be detected. However, the occurrence of multiple failures is low in probability, and to generate a separate and unique stimulus for each module in order to allow for that remote possibility, would have enormously and unacceptably increased the BITE complexity. Although the transmitter unit delivers one kW output, an 18 watt internal dummy load is sufficient for test purposes because of the limited test duty cycle.




BITE OPERATION

LIGHT INDICATES FAULT IN ANY DEVICE PROVIDING CONTINUOUS OUTPUT

OPERATOR INITIATES MODULE FAULT TEST

FAULT DISPLAY INDICATES NUMBER OF FIRST MODULE IN CHAIN TO FAIL

CHARACTERISTICS

ONE SET OF MODULES AUTOMATICALLY TESTED ON-LINE AS A GROUP

OPERATOR INITIATED OFF-LINE FAULT ISOLATION TO MODULE LEVEL

END-TO-END PERFORMANCE TESTED OFF-LINE

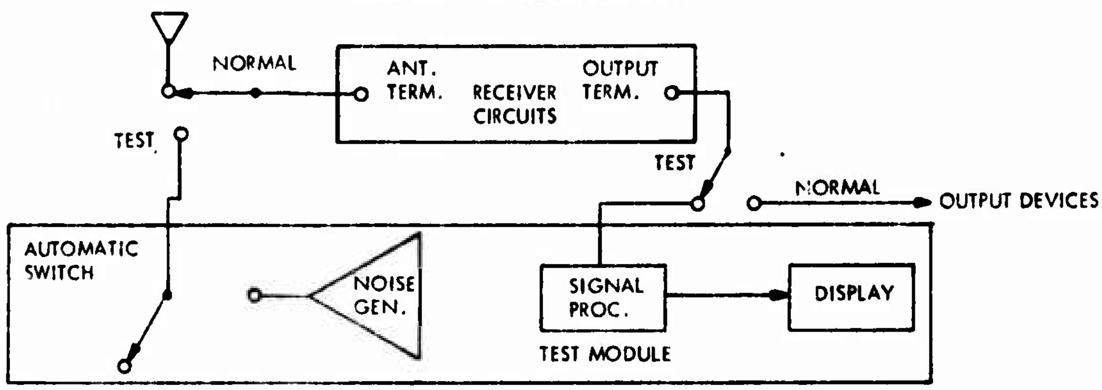
Figure 3-5. Mk LC Radio Receiver BITE

### 3.1.4 Off-Line Testing - General

Organizational off-line testing can be performed by off-line test equipment or it can consist of end-to-end or sub-system testing by BITE or by other on-line test equipment. Module fault isolation can conceivably be performed off-line while the assembly which contains the modules remains in its normal operating location. It is more likely, however, that the assembly will be removed and taken elsewhere to the location of the automatic test facility. Fault isolation in place can be done by probing with manual test equipment, or by the use of portable automatic test equipment. In any case, testing can be facilitated by providing a test connector (as is done for VAST) to enable access to test points without disassembling the equipment. Where test points required for fault isolation to a module are critical with regard to impedance or cross-talk, it may not be possible to wire them to an external connector without degrading performance. One possible solution would be to place an isolation circuit between test point and test connector. The alternative is disassembly and probing of the circuit, which requires dexterity and care on the part of the operator to avoid damage. As with BITE, circuits should be partitioned and modules laid out to facilitate fault isolation.

Off-line fault isolation to a module level can be a two step operation where it is not practicable to bring out the test points necessary to locate the faulty module on the first pass. The first step would locate the malfunction to a group of modules (obviously, the smaller the group, the better), and the modules in that group would be removed from the parent assembly and individually tested manually or by an automatic module tester to pin-point the defective one. The techniques for off-line end-to-end or sub-system testing are similar whether BITE, other on-line test equipment, or off-line test equipment is used. BITE

is handicapped relative to the latter two by the constraints that go with being physically part of the prime equipment. However, BITE has an advantage in closer access to internal test points, which could reduce the need for special test point isolation circuitry relative to requirements with external test equipment. Examples will be given of organizational test equipment which performs tests at higher levels than the replaceable module. NELC has developed a receiver noise figure measuring device which could be incorporated in a receiver as BITE to perform overall tests, or which could be used as off-line organizational test equipment. Figure 3-6 shows the device in a BITE application. The receiver is taken off-line, and a noise generator is used as stimulus, obviating the need for tuning. The noise figure reading developed is a measure of the condition and circuit alignment of the entire receiver.




**BITE OPERATION**

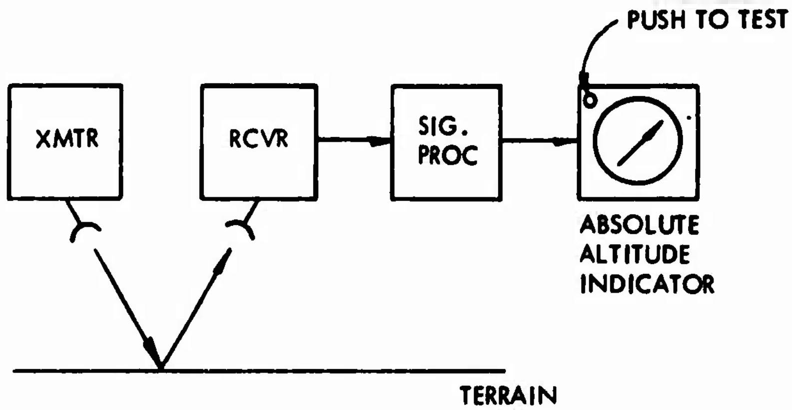
OPERATOR SETS GAIN/SQUELCH CONTROLS AS REQUIRED
OPERATOR SETS BANDWIDTH CONTROL AS REQUIRED
OPERATOR SETS BAND/FREQUENCY OF INTEREST
OPERATOR DISABLES AGC
OPERATOR DISABLES NOISE LIMITER
OPERATOR INITIATES TEST
DISPLAY INDICATES NOISE FIGURE

**CHARACTERISTICS**

OPERATOR INITIATED
NORMAL OPERATION MOMENTARILY INTERRUPTED (OFF-LINE)
END-TO-END PERFORMANCE TESTED

Figure 3-6. NELC Receiver Noise Figure Tester-Shown Adapted as BITE

Figure 3-7 illustrates off-line end-to-end test of an AN/APN-155 altimeter using BITE hardware. The operator depresses a test button which switches a calibrated delay cable in place of the antennas. The indicator will then read the test altitude if the entire set is functioning properly. No faulty isolation is provided.




BITE OPERATION

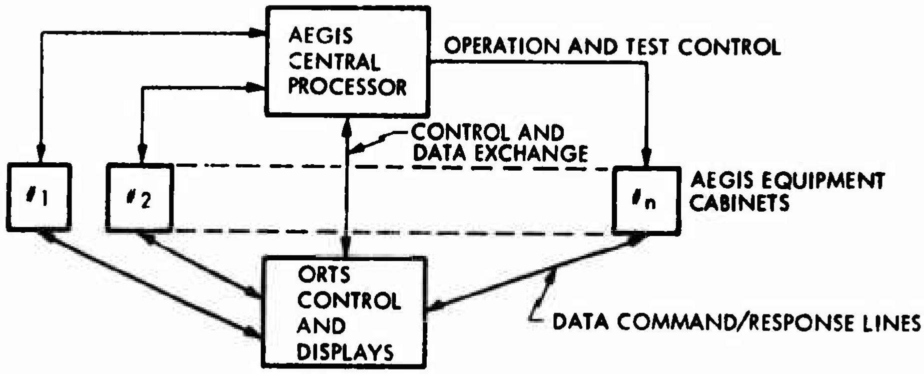
OPERATOR PUSHES TEST BUTTON ON INDICATOR
CALIBRATED DELAY CABLE SWITCHED IN PLACE OF ANTENNAS
INDICATOR DRIVES TO CALIBRATE ALTITUDE
OPERATOR READS AND INTERPRETS RESULTS

CHARACTERISTICS

OPERATOR INITIATED
NORMAL OPERATION MOMENTARILY INTERRUPTED (OFF-LINE)
END-TO-END PERFORMANCE TESTED (LESS ANTENNAS)

Figure 3-7. AN/APN-155 Radar Altimeter BITE

The AEGIS Mk 545 Operational Readiness Test System (ORTS) is depicted in simplified block diagram form in Figure 3-8. This is an example of an on-line (always connected to the prime equipment) centralized automatic test system. It performs on-line and off-line tests from overall system operability down, in some cases, to the module level. Practical limitations on the partitioning of




BITE OPERATION

AUTOMATICALLY AND CONTINUOUSLY TESTS OPERABILITY OF PART OF SYSTEM ON-LINE

PERFORMS OFF-LINE OPERABILITY AND FAULT ISOLATION TESTS UPON OPERATOR COMMAND

CHARACTERISTICS

SHARES AEGIS CENTRAL PROCESSING COMPLEX

SYNCHRONOUS AND NON-SYNCHRONOUS TESTING OF DIGITAL SUBSYSTEMS ACCOMPLISHED THROUGH CENTRAL PROCESSOR

MULTIPLEX SYSTEM SIMPLIFIES DATA GATHERING EQUIPMENT

COMBINED ON-LINE AND OFF-LINE METHODS USED

OPERATOR INITIATES OFF-LINE OPERATION

**Figure 3-8. Aegis Mk 545 Operational Readiness Test System (ORTS)**

the prime equipment, which were largely dictated by logistic considerations, result in fault isolation sometimes stopping at the level of groups of modules. The intent is to use ORTS with a module tester for those cases, providing two step module fault isolation where necessary. ORTS is computer-controlled and shares the data processing sub-system of the AEGIS weapon system which it supports. The only portions of ORTS which are internal to the supported equipment are the interface assemblies through which test data are multiplexed to the ORTS control consoles and computers. Analog test signals are all conditioned and normalized to a dc range, similarly to guidelines established in MIL-STD-1326. Serial and parallel digital signals are acquired through the

data acquisition interface, either synchronously or non-synchronously. Test points are automatically interrogated in a sequence determined by the test software, or by manual override of the operator. Responses are received on the same multiplex data cable, and the shared control processor operates on the data and displays results at control consoles. Although an elaborate system, ORTS services a highly sophisticated weapon system, and the added complexity due to ORTS is estimated at under the 10-15 percent maximum established for BITE. ORTS is an example of organizational equipment which is comprehensive enough to eliminate all additional test equipment except for a module tester.

3.2 INTERMEDIATE LEVEL EQUIPMENT - Hughes Aircraft Corporation

3.3 DEPOT LEVEL EQUIPMENT - Hughes Aircraft Corporation

## SECTION 4

## SELECTION PROCEDURES

The selection procedures described herein are accompanied by background material to familiarize the users with logistic considerations, generic ATE types, and economic analysis methods. The procedures were developed for SYSCOM users and others whose specialty is in the prime equipment for which they are directly responsible, and whose ATE task consists of seeing that the proper resources are directed toward the selection of the most cost-beneficial ATE. Since the ATE selection procedures are essentially intended as project and technical management tools, the background material is held to a level consistent with that intent. No attempt was made to duplicate the extensive library which is available elsewhere to the specialist in logistics, ATE, and economic analysis.

### 4.1 IMPACT OF THE LOGISTIC SUPPORT CONCEPT

Alternative maintenance concepts will be synthesized by the SYSCOM as part of Integrated Logistics Support concept formulation. Maintenance alternatives will be directed toward optimizing acquisition cost, life cycle cost, manning, skill levels, and equipment availability. Alternatives will be based on defining the spares policy, the level of repair and the repair/discard policies at each maintenance level. Maintenance alternatives are likely to be straightforward and consistent for individual equipments or systems. Where an extensive installation of heterogeneous equipment is being planned, as for an aircraft or ship design, maintenance policies can become more complicated.

For example, while it may be economically acceptable to discard defective modules on one equipment because of relatively low replacement cost, such a policy could be prohibitively expensive on another equipment which uses more costly modules. Furthermore, many equipments still in inventory are not modular in construction (e.g., R-390A/URR), and if such equipments are to be repaired at all on a ship, it will have to be to the component level, regardless of the level of repair specified for other equipment on the ship.

The fact that a system or equipment may already be operational under a previously established support concept does not assure that the same support concept will be satisfactory for a new and different application. Different maintenance concepts are possible for airborne, shipboard, and land usage (as by the Marine Corps) of the same equipment.

The level of repair and availability requirements will, of all logistic considerations, have the greatest impact on ATE selection. The ATE will have to provide a fault isolation level which is consistent with the specified level of repair. Since the level of repair policy does not necessarily limit the means for accomplishing the required fault isolation level, the ATE evaluator can consider both on-line and off-line options. However, a tight availability requirement could dictate an on-line ATE configuration for achieving the desired level of repair.

The processes of selecting and formulating the logistic support concept can be iterative, as concepts are successively modified for best match with technical feasibility and cost of the ATE and the prime equipment. The need for iteration is more apt to be evident with BITE than with off-line or external on-line ATE, because of tighter technological, space, and cost restraints.

## 4.2 RELATIONSHIP TO THE ACQUISITION PROCESS

As touched on in Section 2 in another context, and as will become more evident later, the timeliness of ATE decisions is a function of the type of ATE being considered and the point in the acquisition process at which deliberations are in process. Generally, on-line equipment must be selected earlier in the acquisition process than off-line equipment, with BITE being the most critical on-line approach with regard to timing. Since BITE is part of the prime equipment, decisions relative to its use and functions must be made during the Conceptual Phase. If decisions are deferred until validation, potentially costly design changes may be called for. External on-line test equipment should also be selected during the Conceptual Phase, although the risk incurred in waiting until Validation will be less than in the case of BITE, and will depend upon the amount of interface equipment which will have to be added integrally to the prime equipment design. The selection of off-line test equipment could be (and often is) deferred until prime equipment production or beyond. However, it is much more desirable to select the ATE no later than Validation, because the designer can realize in advance the need to configure the prime equipment to facilitate test point accessibility. He can also partition circuitry for easier fault isolation, with significant benefits in testability, test time, and ATE adapter and software costs, if he is made aware of the ATE being contemplated while he is designing the prime equipment.

## 4.3 THE GENERAL PROCEDURE

### 4.3.1 Introduction

The general procedure for evaluating and selecting ATE systems is keyed to the definition of the prime equipment logistic support concept. The logistic support

concept matures in parallel with the prime equipment acquisition concept, as MEAs are updated to reflect the increasing level of available detail concerning configuration of the prime equipment. As stated previously, the ATE selection procedures were developed to assist SYSCOMS in managing the ATE portion of prime equipment programs, which involves directing and coordinating the work of specialists assigned the details of that task. ATE specialists, if not already resident in the SYSCOM, are envisaged as being enlisted from other Navy organizations or from private industry. A Test Equipment Support Office (TETSO) has been created at NELC as a source of ATE expertise, and TETSO engineers could either be assigned full-time to the respective SYSCOM if the task warranted, or could provide consultation on an ad hoc basis. The risks of implementing an ATE selection procedure without the assistance of ATE specialists are very great. Over-specifying of ATE performance can arise from unfamiliarity with state-of-art limitations. Under-specifying to avoid the first risk can result in a less than optimum support system. Early in the acquisition process, where technical details are sparse on both the prime and the candidate ATE system, prime equipment and ATE specialists must work very closely. Later on, the need for the prime equipment specialist will still be required to provide an informal evaluation of the firm candidates. Later in the report, modeling aids are suggested to augment human judgment in the selection process.

### 4.3.2 Systems in Development

For systems still in development, or contemplated to be in development, entry to the procedure is at entry point 1 in Figure 4-1. Details of equipment to be supported would not be firm. However, equipment could be described in terms of the numbers to be deployed, where they will be used, and their function (e.g., shipboard HF communications). During preliminary design, reliability

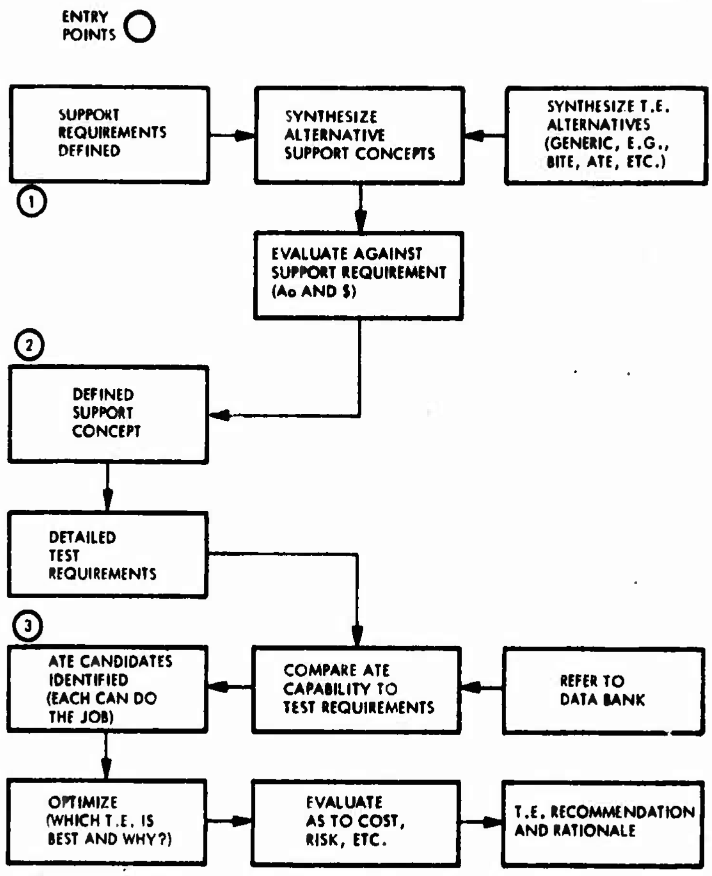



**Figure 4-1. Support and Test Equipment Evaluation Procedure**

data and equipment configuration in terms of module quantity could be synthesized by similarities to existing equipment. The maintenance workload is a function of MTBF's, MTTR's, requirements for system availability, etc. From these requirements the procedure should provide guidance in synthesizing alternate support concepts such as built-in test, module discard, intermediate level module repair, etc. The test equipment alternatives would at this point be synthesized and described generically, that is, general purpose ATE, module tester, Go/No-Go BITE, etc. Some alternatives would exist in combinations such as, for example, built-in test for overall operational monitoring,

and off-line testing for module fault isolation. A support concept would be selected from evaluation of alternatives on the basis of operational availability (Ao), hardware and manning costs.

### 4.3.3 Support Concept Defined

At entry point 2, the support concept has already been defined either as a result of the previous steps, or through other means for defining the maintenance policy. The next step is to define in detail the technical requirements for testing the equipment to be supported. For all levels of test required by the support concept, down to the lowest level of fault isolation, test requirements must be defined in terms of switching, stimulus, and measurement capabilities. Included would be details on accuracies, programmable increments, waveforms, spectral purity, etc. Where design status is insufficiently advanced, or schedule pressures do not permit, details may be lacking, and the burden will fall on the ATE specialist to fill in the gaps based on judgment and experience. The detail and format for describing test requirements would have to be similar to those used to describe existing test equipment alternatives in a data bank expected to be created for that purpose. Test requirements would be compared to ATE capabilities in the data bank, and test equipment alternatives would be identified which meet test requirements. If the ATE data bank does not provide a satisfactory match, one or more new ATEs must be specified and evaluated.

### 4.3.4 ATE Candidates Identified

At entry point 3, ATE candidates have been selected through previous steps of the procedure, or through some other process. The remainder of the procedure is concerned with evaluating the alternatives - essentially on the

basis of economic factors - and selecting the optimum configuration. Acquisition cost, manning cost impact, program risk, and delivery are some of the factors to be considered. Although it is anticipated that the optimization process can be mechanized throu h an economic analysis model, the judgment of the ATE specialist may be called upon in the final selection, if only to provide inputs to the model in the form of risk factors, degree of desirability of excess test capability, etc. The final result is selection of the optimum ATE to meet a maintenance concept, and the rationale to justify the selection to the eventual user of the equipment.

## 4.4 FROM SUPPORT REQUIREMENTS TO SUPPORT CONCEPT DEFINITION

### 4.4.1 General

The first part of the evaluation procedure, the portion between entry points 1 and 2 on Figure 4-1, is expanded and described in this section. This is the only time in the acquisition process where it may be economically feasible to specify built-in or on-line test methods. At this time plans can be made for integral test devices or for an interface with external test equipment. Later in the acquisition process, the addition of test equipment provisions can become prohibitively costly, because of the need for design changes. The ideal subject for ATE application would be an all new weapon, radar system, or radio. New aircraft and ship designs usually contain a mixture of new and existing subsystems and equipment, which complicates the ATE selection process, pointing toward a mix of manual and automatic testing. Figure 4-2 summarizes the process to be described and suggests the organizational responsibility for each step. Later portions of this section will elaborate, where necessary, on the steps shown in Figure 4-2, and which are briefly discussed below.

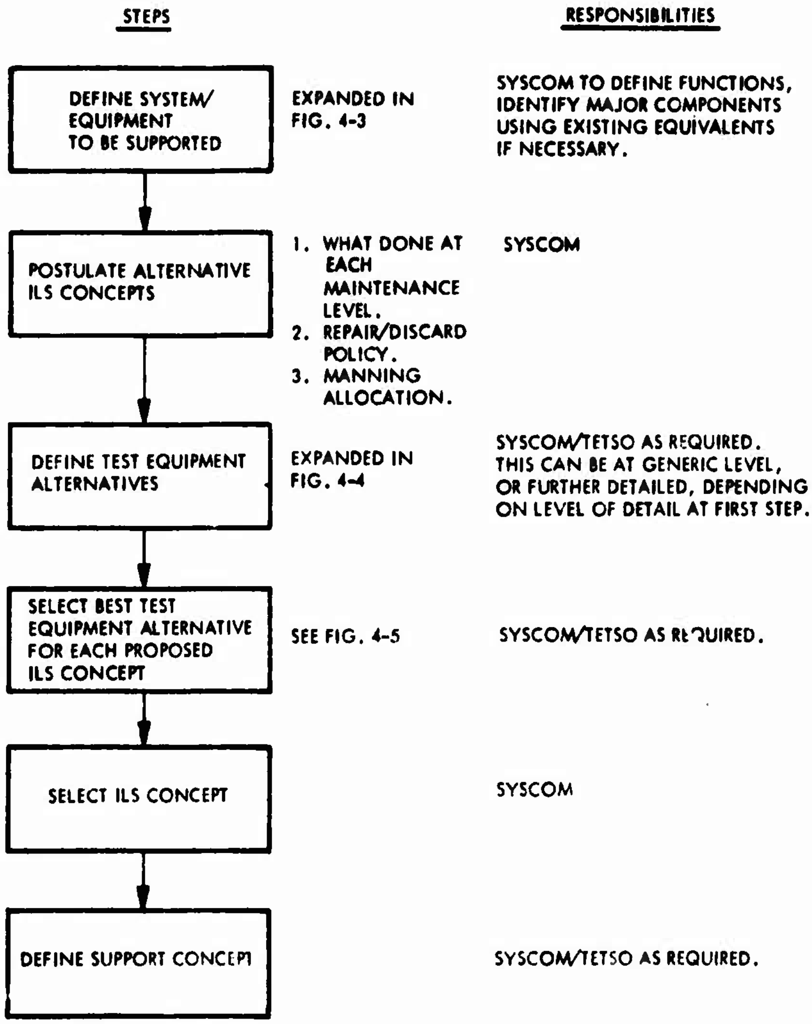



Figure 4-2. Support Concept Definition

(1) Define System/Equipment to be Supported - A basic first step, and the responsibility of the SYSCOM, is to define the equipment or system to be supported.

(2) Postulate Alternative Integrated Logistic Support (ILS) - The SYSCOM is seen as performing this task, which essentially consists of identifying ILS concepts for comparative evaluation. Although this step is not a part of the ATE selection and evaluation process, the two are mutually dependent.

(3) Define Test Equipment Alternatives - Definition of test equipment alternatives may require that SYSCOM be assisted by TETSO or other technical groups with ATE backgrounds, unless the SYSCOM has the capability in-house. Possibly, a number of test equipment alternatives may be suggested for each alternative ILS concept. The detail to which ATE alternatives can be specified will depend on the level of detail available to describe the equipment to be supported (first step in Figure 4-2).

(4) Select Best Test Equipment Alternative - A cooperative SYSCOM/TETSO task is envisioned to select the best of the test equipment alternatives for each alternative ILS concept. Selection criteria will include ILS, cost, and technical factors.

(5) Select ILS Concept - Although not strictly a step in the ATE selection and evaluation process, the selection by SYSCOM of the maintenance and related integrated logistic support concepts will determine the ATE concept, since the ILS alternatives will each have included an ATE alternative from the previous step.

(6) Define Support Concept - This is essentially the paper-work task of defining the previously selected ILS concept in terms which can be understood by those concerned with the ILS interface. The related task of specifying the ATE is seen as requiring an ATE background.

### 4.4.2 Define System/Equipment to be Supported

The validity of the ATE selection and evaluation process depends largely on the level of detail to which the supported equipment can be described. The supported equipment could consist of an aircraft or ship subsystem or group of subsystems. It could comprise an entire missile weapon system, or simply.

an individual equipment. Figure 4-3 expands the single step shown at the beginning of Figure 4-2 into a number of levels of detail. The levels are arranged in order of increasing detail going from top to bottom, and their significance is discussed below.

Budget - Cost, Space, Weight, Power: These are typical budgetary parameters which apply to the equipment to be supported. A bound on acquisition cost can be eased by proving a life cycle cost reduction which exceeds the acquisition cost increase due to the proposed ATE by a sufficient margin to make a

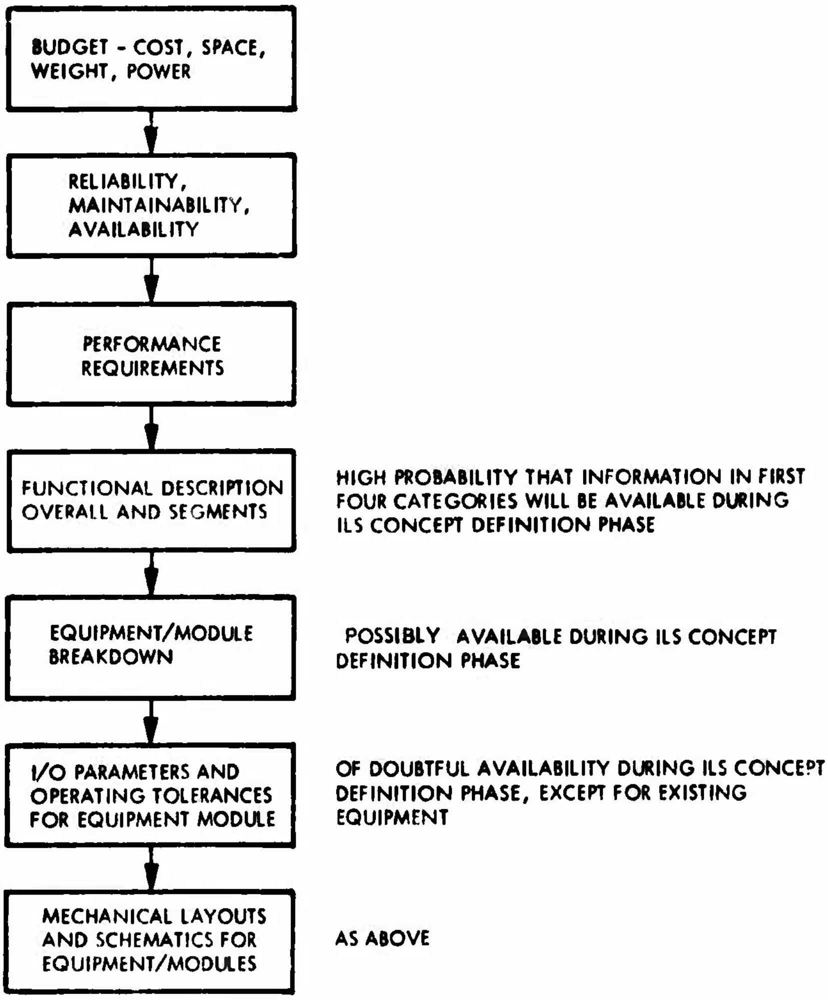



Figure 4-3. Define System/Equipment to be Supported

credible case. Space, weight, and power constraints are more confining, particularly in airborne applications. However, continuing micro-circuit developments promise significant future size reductions.

Reliability, Maintainability, Availability (RMA): Early in the development phase, RMA factors will exist only as predictions, if at all. Reliability and maintainability factors should be used conservatively. Mean-time-between-failure (MTBF) and mean-time-to-repair (MTTR) are, by definition, means. Actual failure and repair times can deviate from those means. Also, because of human error, skill level variations, and other factors, operational experience is apt to be worse than the predictions. Operational availability will be based on mission scenarios, and is likely to be a firm requirement.

Performance Requirements: Performance requirements are needed to synthesize end-to-end performance monitoring systems, whether built-in or external. An initial idea of the complexity of such a system can be estimated from the accuracy, stimulus, and measurement requirements implicit in the performance specification.

Functional Description - Overall and Segments: This level of definition is a further expansion of performance requirements. Functional descriptions should get down to segments of the system or equipment to be supported. From this information it is possible further to define BITE devices and to start defining off-line ATE alternatives for lower levels of testing. If no further definition of the supported equipment can be made available, this level of information will enable module breakdown estimates to be made by an engineer who is familiar with similar existing equipment.

Equipment/Module Breakdown: At this level, the hardware configuration of the supported equipment will start to be defined. For equipment in the planning phase, it is unlikely that this level of definition will exist, except as similarities to existing equipment. During the Conceptual or Advanced Development Phases, this information can be synthesized, but changes (20 - 50%) can be expected during the Validation or Engineering Development Model Phases. Generation of this information will enable medium confidence level synthesis of alternative ATE configurations suitable for module level repair.

I/O Parameter and Operating Tolerances: The input/output parameters and operating tolerances for equipment assemblies and modules are necessary for synthesis to a high confidence level of ATE to the module repair level. This information will define measurement and stimulus requirements and accuracies. Equipment would have to be well along in design, perhaps 75 to 100% complete, before reliable module operating parameters could be available. Obviously, it is highly improbable that these details would be known for new developments during the ILS concept definition period, except on the basis of close similarities to existing equipment.

Mechanical Layouts and Schematics: Mechanical layouts and schematics are essential to the design of ATE interface hardware internal to the supported equipment, of external adapters, and the ATE interface. This information will only be available on existing designs. However, for planning and costing of alternative ATE configuration for new development, it should be possible to estimate these items based on past experience. The estimating errors may be high but should not be significant in the overall cost context.

Availability of Information: There is a high probability that the first four of the seven levels, (that is, down through functional descriptions) of supported

equipment definition previously discussed will be available during the ILS concept definition phase of a new equipment. By the time the remaining three levels have been determined, the ILS concept will already have been defined, and the supported equipment will be heavily into the Validation Phase.

### 4.4.3 Define Test Equipment Alternatives

General: For each alternative maintenance concept there may be more than one test equipment alternative. An extensive shipboard installation where repair to the module level is being considered could include an ATE to fault isolate to the module, and a separate module tester to locate the faulty component on the module. A single ATE system could also handle both levels, or a separate module tester could be used in conjunction with BITE to locate the faulty module. Possibly, the faulty module could be located by manual methods, aided by convenient access to test points.

The total number of ATE alternatives need not increase proportionally to the number of maintenance concepts. A considerable degree of ATE commonality can exist among maintenance alternatives. Identical module testers could be proposed for use on shipboard (Intermediate Maintenance Activity) or at the depot.

Figure 4-4 outlines the process for defining test equipment alternatives. The process can be iterative, as shown, with feedback which can alter the original maintenance concept. Although this portion of the procedure is concerned with ATE selection during the ILS/maintenance concept definition phase, the same sequence of tasks, but in much greater depth, is required further along in the acquisition of the supported equipment.

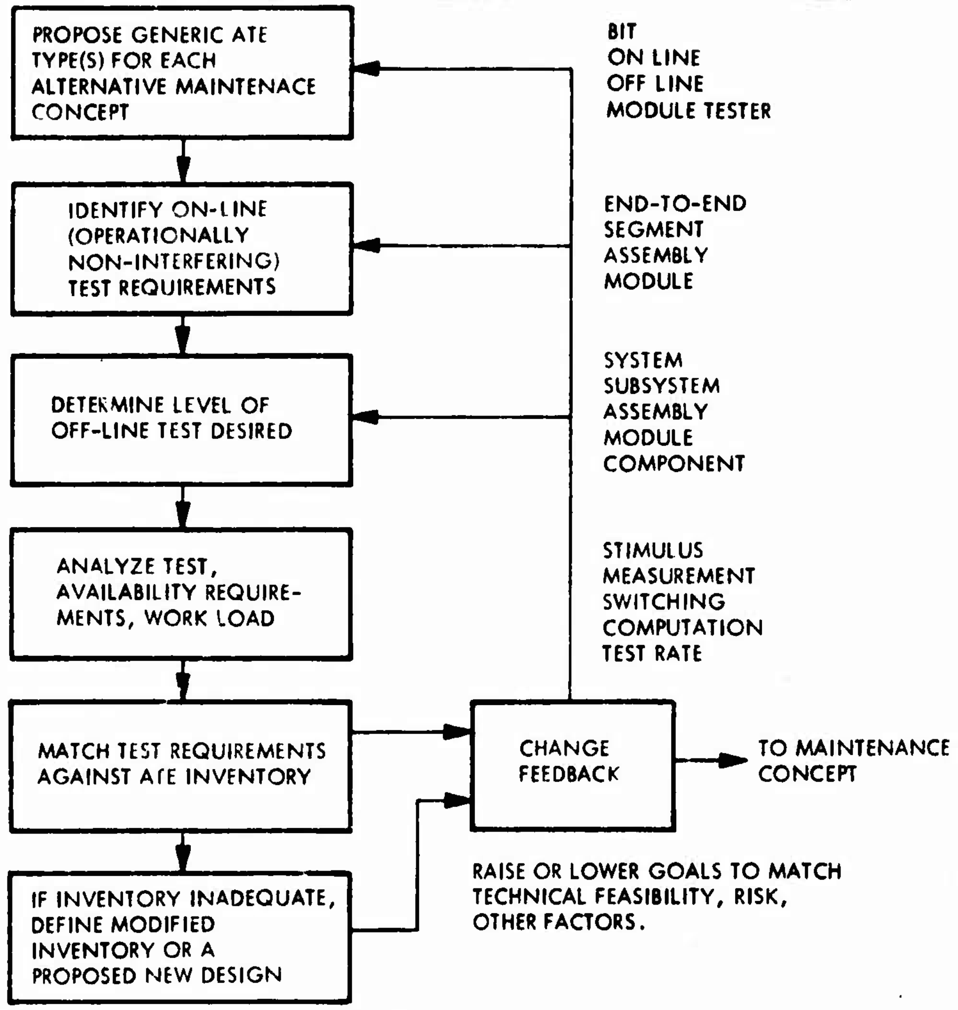


Figure 4-4. Process for Defining Test Equipment Alternatives

Generic ATE Types: The first step consists of proposing generic ATE types compatible with the particular maintenance alternative under study. The range of ATE types will depend as much on the type of equipment to be supported as it will on the maintenance alternative. A wide range of options is open (and necessary) for systems consisting of a number of equipments, as compared to individual equipments. Typical systems which may be encountered are ship's communication, ship's machinery, shipboard tracking radar, terrain following radar, and air defense systems. (The dividing line between an equipment and a system is arbitrary and not particularly significant. A system can be considered

to be an operating entity consisting of more than one equipment.) The possible generic ATE options for a system can be made up from one or a combination of the following:

(1) Built-in test equipment (BITE)
(2) Other on-line test systems
(3) Off-line test systems
(4) Module testers

In addition, the generic ATE options above can each be further broken down into one or a combination of the following optional operational modes:

(1) On-line (noninterference with equipment operation during test)
(2) Off-line (opposite of on-line)
(3) Performance monitoring (end-to-end test)
(4) Various fault-isolation levels - segment, assembly, module, component

<u>Identify On-Line Test Requirements:</u> The mission will have to be analyzed to determine the need for on-line monitoring. From an operational and maintenance viewpoint, on line monitoring (or testing) is the most desirable mode of operation. However, cost and technical considerations could require that on line monitoring be limited to mission-critical parameters. On-line testing can be specified for end-to-end, segments, assemblies, and even modules, where it is technically possible.

<u>Determine Level of Off-Line Test Desired:</u> Many of the comments made regarding on-line test requirements are also applicable to off-line testing. The major difference is that the lowest level of fault isolation - down to the component - can be specified with a much higher degree of confidence for

off-line test equipment operating in an off-line mode than for on-line configurations. The degree of fault isolation attainable in off-line operating modes has so far tended to be least on BITE, increasing with centralized external test systems, and achieving a maximum on depot type test sets or module testers. Exceptions are possible in individual cases, but a thorough technical understanding of the equipment to be monitored and of ATE technology is necessary to avoid over-specifying test requirements.

Analyze Test, Availability Requirements, Workload: To analyze test requirements in detail sufficient for precise specification of ATE and its software requires information on the supported equipment which will not be available until it is almost completely designed. Therefore, until that time, this step will have to rely very heavily on the judgment of an ATE specialist who is also familiar with the proposed design of the equipment to be supported. As previously mentioned, new ships and aircraft will use significant amounts of hardware already in inventory. However, BITE and centralized testing (except on a gross end-to-end basis) will usually be ruled out for existing equipment because of the high cost of modification for either test approach. Centralized testing, which requires the lesser modification, still requires an often costly and space-consuming integral interface. For those equipments it will be possible to determine detailed test requirements for maintenance levels where off-line ATE can be used. Equipment still in the planning stage will require the ATE specialist's judgment to identify stimulus, measurement, switching, and computational requirements, and these obviously can enable ATE specification to the A level (MIL-STD-490) at best, because of the preliminary state of the equipment design.

The desired impact of ATE on MTTR must also be analyzed. This will require acquisition of projected reliability, maintainability, and availability data.

In effect, a figure will be derived which states the turnaround time for a UUT to be processed through an off-line ATE installation. (The time to detect faults with BITE or other on-line ATE is usually negligible.) A total workload can then be determined by adding individual processing times for each UUT. The result will be an indication of desired test rate, which, because of set-up and other irreducibles could require a number of identical test systems or a mixture of different types (e.g., VAST plus x module testers).

Match Test Requirements Against ATE Inventory: At this point a set of test requirements will exist. The level of detail will depend on the depth of technical information available on the supported equipment, the time available to assemble the test requirements, and the judgment (and prescience) of the ATE specialist. If a data bank exists to describe current ATE inventory, the test requirements should be in the same format to facilitate comparison of requirements with available capability. This comparison can be done by the specialist, or, if the complexity of the task warrants the cost of automation, it can be done by a computerized data bank and a comparison algorithm. The results of the comparison will fall into the following categories:

(1) Location of one or more candidates
(2) Identification of one or more near matches
(3) Nothing suitable in inventory

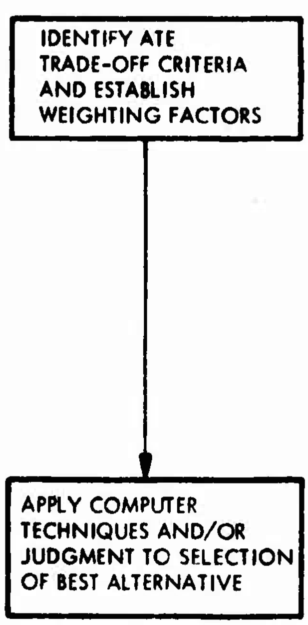
When Inventory is Inadequate: When a comparison of test requirements against ATE inventory discloses nothing entirely suitable, the ATE specialist has several choices. He can locate the best match to his requirements and consider modifications to the inventory item to eliminate the shortcomings. He can accept the inventory ATE as is and reduce his requirements. He can specify

an all-new design. Even when a suitable ATE is found in inventory, a new or modified design might also be considered because of cost, size, over-capability, etc.

<u>Change Feedback:</u> At this point a number of ATE candidates exist. They have yet to be evaluated, and a final selection made. However, the degree to which the originally proposed generic types and test requirements are technically feasible will at least be apparent. Original goals can then be raised or lowered to minimize risk and more closely to match technical realities.

### 4.4.4 Selection of Test Equipment From Alternatives

The basic evaluation criteria for selecting an ATE system for a particular maintenance concept are cost and supported system/equipment availability. There are many factors to be considered in a trade-off. These are tabulated in Figure 4-5 and are amplified in following sections. Each factor must be




IMPACT ON UUT ACQUISITION COSTS
IMPACT ON UUT MAINTENANCE AND SPARES COSTS
IMPACT ON LIFE CYCLE COST
IMPACT ON AVAILABILITY
TECHNICAL FEASIBILITY/RISK
SCHEDULE FEASIBILITY/RISK
ATE ACQUISITION/REACQUISITION COSTS
- HARDWARE
- SOFTWARE
- UUT INTERFACE
- SPARES
- DOCUMENTATION

ATE RELIABILITY, MAINTAINABILITY, AVAILABILITY
ATE MANNING AND SKILL LEVELS
SPACE
WEIGHT
POWER
GROWTH

Figure 4-5. Selection of Test Equipment From Alternatives

weighted by the evaluator to suit the particular application. The SYSCOM, which has the ultimate responsibility for cost, system availability and performance, should be heavily involved in the evaluation. The SYSCOM can best determine how much it can pay for a given increase in availability, or for future growth capability, or how acceptable a proposed increase in acquisition cost may be for a projected life cycle cost saving. Evaluation of technical risks and the creation of work-around paths will require the combined technical and management ingenuity of an ATE specialist and the SYSCOM.

Impact on Supported Equipment Costs: The introduction of ATE will result in individual positive and negative impacts on supported equipment costs. Where the net impact is an increase, the ATE alternative will be acceptable only if a compensating advantage can be demonstrated. In the case of AEGIS, the incorporation of ORTS as an on-line test system undoubtedly increased the AEGIS system acquisition cost, but without it, availability would have been unacceptable. A description follows of supported equipment cost categories which can be influenced by ATE alternatives.

Acquisition Cost: ATE will drive the acquisition cost of supported equipment upward when ATE must be specially procured or built-in to the supported equipment. Where an ATE will already exist for use elsewhere, but which can also accommodate the supported equipment under study, acquisition costs can still increase if hardware must be added either internally or externally to the supported equipment to provide an interface with the ATE system, or where additional software is required. Where BITE or an ATE interface is being considered internally to the equipment to be supported, the individual cost is multiplied by the production quantity. Difficult to justify, unless spectacular results are indicated, is the modification of existing equipment, where the modifications will only affect part of the population of that equipment. This is

typical of the situation where a centralized test system is being contemplated for production communication gear on a ship. The modification design will encounter technical problems in the way of space, weight, power, and electromagnetic compatibility. Then, further costs will be incurred for a requalification program and a new documentation and spares package to support what might end up as a new equipment designation.

ATE can also drive acquisition cost downward, when improvements in availability accruing from use of ATE can reduce the need for redundancy, or reduce the production quantity originally planned on the basis of a longer MTTR without ATE.

Maintenance and Spares Costs: ATE will tend to reduce maintenance and spares costs. Maintenance manpower skill levels will be reduced by more rapid automatic detection and isolation of faults, which reduces the time and simplifies the task of repair. Spares costs can be reduced by isolating faults to a level which might be impracticable to achieve manually, thus reducing the complexity of the spares to be stocked. Further cost savings can be effected by shortening the turnaround time through the use of ATE at the depot or intermediate facility, thus reducing spares pipeline times and quantity required.

Life Cycle Cost: Life cycle cost calculations will include all costs, including related ATE costs, to acquire and support the equipment for its estimated life. ATE will tend toward reducing life cycle cost because of maintenance savings. However, this must be balanced against ATE costs. The value of improvements in availability are difficult to quantize unless a clearly identifiable reduction in supported equipment production quantity can be identified from the use of ATE. However, the SYSCOM should place a value on availability

improvements when considering life cycle cost. There is an obvious political problem in balancing acquisition cost increases against life cycle cost reductions. The case for such an increase must be clear and credible. The agency responsible for the acquisition budget may be reluctant to support an increase now in exchange for a saving in the future, when the future saving will accrue to another agency.

Direct ATE Costs: If an ATE is located in inventory which meets requirements, its reacquisition cost will have to be estimated. If the ATE is no longer in production, the hardware acquisition cost can far exceed the original manufacturing cost because of start-up and inflation costs. A new ATE can be estimated on the basis of cost information for existing ATE, modified by inflation escalation factors and allowances for new technology. Software costs will also need to be estimated. Software cost can vary considerably from machine to machine for a given unit-under-test (UUT). The existence of software preparation aids, such as compilers and standardized languages, are potential means for reducing the cost of preparing individual programs. The creation of software aids is usually very costly, as compared to almost any test program. A rule of thumb sometimes used is to estimate $100.00 per test, where a test is defined as a stimulus-response combination or a comparison-go/no go decision. Digital test programs can be reduced to around $10.00 per test using automatic test program generation methods.

The UUT interface can be a significant cost item. For off-line ATE, the interface consists of a connecting cable and usually an adapter box or fixture. The adapter box will include dummy loads and sometimes considerable electronic gadgetry which is too special in nature to warrant integrating into the ATE. A minimum interface, then, could cost under $100.00. The maximum can run as high as the benefits will justify - easily into the thousands of dollars.

Support costs in the way of spares, documentation, and maintenance manning requirements for ATE should also be considered.

Technical Factors: The ATE RMA figures are important evaluation factors. A complex ATE is subject to the same statistical reliability hazards as a complex supported equipment. The difference is that a self-test function is inherently easy to build into ATE. Reliability and maintainability will influence maintenance manning costs, previously mentioned. They will also determine availability and, therefore, UUT turnaround or flow rate.

The technical risks must also be evaluated. An over-ambitious set of technical requirements could result in technical problems which are impossible or impracticable of solution because of time, money, and state-of-the-art constraints. Where a serious risk is recognized, requirements may have to be reduced. Where the risk is marginally acceptable, an escape route should be plotted which will allow for a change of plan just before the point of no return.

Space, weight, and power requirements for ATE can vary from trivial to extremely important evaluation criteria. The weighting factors obviously depend on the application. In order of increasing gravity, they are depot, aircraft carrier, destroyer, submarine, aircraft.

Growth capability, or flexibility, defined as capability in excess of current needs or as provisions to facilitate future expansion, can also be an evaluation criterion. However, this factor is largely subjective when it comes to placing a dollar value on it.

Technical pressures can generate a pronounced bias toward the very latest techniques and make it difficult to reprocure an existing system. This bias must be counterbalanced in the ATE evaluation process by consideration of the possible costs and the benefits of the new technology to the prime equipment.

## 4.5 MODELING AIDS

### 4.5.1 Logistics Models as Tools in Early Planning for Support

Integrated logistic support is a composite of all the support considerations necessary to assure the effective and economical support of a system for its life cycle.[1] It is an integral part of all other aspects of system acquisition and operation. ILS begins with program initiation (conceptual and validation phases), and continues through full-scale development, production, and deployment.

The choice of test equipment is inherent in the ILS process and the alternatives available to the acquisition manager are not the same for each phase in the life cycle. During conceptual effort, the focus is on system feasibility studies and the major output is the basis for a decision as to whether a system acquisition program should be pursued. Support activity during the conceptual phase is concerned with defining the maintenance environment, the interface with the logistic systems, and such goals as MTBM and MDT. That is, the support activity is dealing with requirements which will be the basis for later selection of test equipment to meet the requirements.

In the advanced development phase, the requirements for BIT/BITE are developed and baseline maintenance concepts are specified. The role of separate test equipment emerges at intermediate and depot levels in relation to BIT/BITE.

During conceptual effort and advanced development, various simulation processes are used to anticipate the effect of different approaches. Firm descriptive data, (such as exact frequencies of operation, equipment failure rates, etc.) is not

1 Integrated Logistic Support - Implementation Guide for DoD Systems and Equipments - NAVMAT P-4000, March 1972.

available. The relationship of many variables (such as failure rate as a function of equipment utilization) is better known than the numbers themselves. In such a situation, simulation processes are useful in giving an answer to "what if" questions. For example, what if the required operational availability is so high that MDT cannot exceed ten minutes? Or what if there were no intermediate level of support, and faulty items were returned from the fleet user directly to depot? The tools which simulate the relationship of the variables in a process are called models. Models are a part of the ILS tools of the trade. They are used to indicate what is significant and what is not in planning the long term support of an equipment.

They can anticipate the effect of suddenly increasing the usage rate of an equipment by a factor of 2:1 or the savings in support costs of achieving an additional 10 percent MTBF during design.

The logistician uses models to help define the elements of logistic support in time to impact design, plan for equipment deployment, and control O&M costs. Models can also be useful to those concerned with implementing the support concepts developed by the logistician, i.e., those concerned with selection of test equipment.

### 4.5.2 Decision Points Which Can Be Supported By Modeling

Figure 4-6 indicates the phases in an equipment's life cycle and the test equipment related activities are indicated in the flow of tasks. There are many other activities which are not shown; the activity flow was drawn especially to emphasize test equipment related elements.

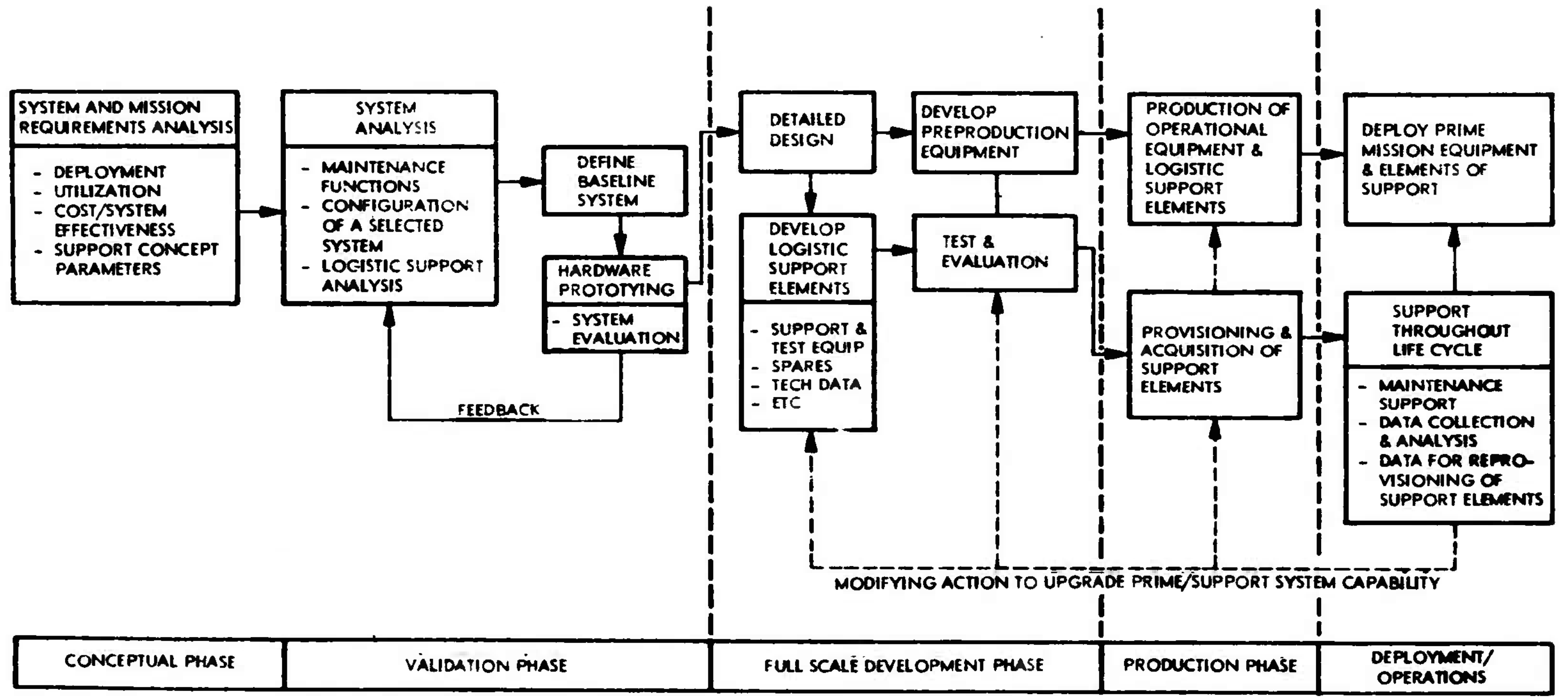



Figure 4-6. Equipment Life Cycle

In the conceptual and advanced development or validation phase, test equipment decisions are of the type "what generic kind of test equipment should be anticipated in support of these operational and maintenance requirements"? It is too early in the life cycle, for most prime systems, to select test equipment A or to evaluate test equipments A, B, and C. Rather, the range of decisions would include a choice of :

- Whether an operational availability can be better achieved with built-in test, separate test equipment, or a combination of both
- Whether board and subassembly fault isolation/repair can more effectively be accomplished using manual general purpose test equipment, general purpose ATE, or special purpose ATE unique to the prime mission equipment
- Whether overall savings accrue from using the same test equipment at intermediate and depot levels although the testing requirements are different.

Before moving to full-scale development, the support concept should be defined (level of repair, built-in test decisions, etc.). Models will be very much in evidence as the support concept is firmed and early test equipment decisions are made. At this stage input data consists of such operational parameters as:

- Availability
- Utilization rate
- Deployment
- Reliability

and such program requirements as

- Unit cost targets
- Service life

A second area where models are likely to be useful in supporting test equipment decisions is during development and production. During some time in the development phase, a specific test equipment must be selected. This test equipment may be a developmental requirement described by an equipment specification; it may be itself in development.

The input data available to the model would consist of:

- Specific prime equipment test requirements (frequencies, voltage levels, accuracies)
- ATE/UUT interface requirements in terms of number and types of connectors, test access points, power requirements
- Workload requirements in terms of the numbers and types of UUTs per unit time which arrive at the test station
- Personnel subsystem characteristics, operator training assessments.

In general the input data could be expected to be quantitative, with an accuracy confidence derived from design data and limited test/evaluation. Sensitivity analysis would be used to identify parameters critical to the ATE selection.

A third application for support system modeling is when the overall support resources must be estimated. Support resources are all the elements of test equipment, spares, operator/maintenance personnel, tech data, periodic calibration, etc. which are needed to maintain the prime mission equipment. After

an equipment is deployed with the fleet, along with supporting test equipment, there are frequently changes in the number of equipments, in where and how they are used, and as significant modifications to the basic equipment. When such changes are contemplated, modeling techniques are useful in anticipating the impact of change. For example, increasing the number of equipments aboard ship may change the test workload such that an additional test equipment is needed. Models are used to anticipate the total resource requirements resulting from:

- A modified support concept, such as off-loading board repair to intermediate or depot level (such as Project Blackball)
- The opportunity to replace obsolescent test equipment with more efficient newer design
- Major modification to a shipboard electronic equipment, which results in new test requirements
- COSALS for a new ship class, where combined test requirements are the basis for shipboard test equipment selection
- Fleet data indicating significant increase in prime equipment failure rates and therefore reduced maintenance workload.

The models discussed in this section are mathematical models. That is, the relationships of independent and dependent variables in the maintenance process are expressed in mathematical terms and converted to a program which runs on a general purpose digital computer.

There are two basic approaches to expressing the relationships within the model and each approach has distinct advantages and disadvantages for one or another

application. The two approaches are identified as analytical and simulation models. The analytical model provides a single answer or set of answers for a given set of inputs. The analytical model gives an answer for all input values held fixed. The simulation models trace the behavior of the process over a time period during which key variables are allowed randomly to assume some value within its range of possible values.

### 4.5.3 Generic Model Types and Their Characteristics

Analytical Models: It is generally a characteristic of analytical models that they provide solutions with relatively small computation effort. The relationships between various factors may be complex but most likely or best estimate values are used to obtain a single point solution.

The formulations within the model are of a type in this simple example:[2]

$$AFD = IUD/(UD + IUD)$$

where

AFD = an apportioning factor for support equipment at depot

IUD = item utilization of support equipment at depot

UD = utilization of depot level repair support equipment per month on other items.

2 A Preliminary Report on the Final NAVSHIPS Level of Repair (LOR) Model - Virginia Research, Inc., February 1973.

AFD is expressed as a fraction of time, such as .3 or .4 while IUD and UD are in hours and hours per month respectively.

Most reliability models are analytical models, based on a formulation relating the probability of occurrence of various events. The function of failure rate prediction is closely related to maintenance workload estimation.

Other analytical models are useful in examining processes which involve the flow of material between geographic locations, such as repairable items and spares stocks between maintenance levels.

It is a characteristic of analytical models that computer running time is short - on the order of seconds or a few minutes. This means that the user can expect to get responses quickly and cheaply, and he will be able to iterate various solutions as the most significant characteristics emerge in the trial solutions.

Typically, the technique of sensitivity analysis is used within analytic models as a way of handling input data uncertainty. The classical parametric study is an example of sensitivity analysis, where a range of solutions are presented for variations of a key input factor. The factor is allowed to assume values from a lowest likely to a highest likely value. Examples of sensitivity analysis will be shown in the section on input data requirements.

Every model falls short of being an exact replica which correctly relates all factors in the modelled process under all possible conditions. As such the model is a compromise, attempting to provide an adequate representation without becoming so complex or so demanding of input data that it is unwieldy to use. A support system model which neglects ATE spare parts costs would

probably not adequately represent significant cost elements; a model that required an individually priced spare parts list would require more effort than it is worth in generating input data.

Typical input data would include that shown in Table 4-1. The input data requirements are more a function of the process being modelled than of the type of model. Additional information about input data is provided in the Input Data Requirements section.

Table 4-1. Example Problem Data Base

- Deployment Factors - Number of systems supported, geographical location, utilization rate, support hierarchy to include relation to organizational structure, and work week.
- Equipment Factors - Equipment breakdown, units, modules, parts; failure rates; physical characteristics; operating times; and costs per unit, module and part.
- Supply Factors - Stockage policies, supply times, production lead times, stockage costs, and transportation factors.
- UUT Modifications - Modifications of fleet UUTs and the provision quantity during the operational phase of the program.
- Test Equipment Factors - Test equipment characteristics, costs, and support maintenance requirements.

Analytical methods are particularly applicable to reliability and maintainability models, to resource allocation models, to life cycle cost and logistic models, and to optimization problems where the best of alternatives is to be chosen.

Simulation Models: "Systems characterized by large data banks or sizable solution sets can be handled with simulation models. Simulation traces the

system's behavior, frequently over time, under a specific group of constraints, such as initial conditions, exogenous and design variables, target conditions, and internal structural properties. Functional relationships exist between the solution parameters and the control or state variables in the model, and in some cases the solutions are not obtained as point estimates but rather as intervals that contain the correct answer.

Although simulation is frequently implemented for complex situations, it is not necessarily true that the solution implied from a given set of input data is optimal. Instead, it represents an approximation to the best answer, and the modeler must introduce various input combinations to compare their implications for the desired goals in the system analysis. Yet, even with the selection of many different input data, the attainment or realization of an optimal solution cannot be assured as it is for the analytical approach.

Although simulation is generally more adaptable to large-scale computational problems than analysis, it also gives approximate solutions whose optimality may, or may not, be justified on theoretical grounds. Further, simulation models are generally larger, more difficult to debug and validate, and more expensive to run than analytical models. They can be used, however, to analyze situations that are just too complex for analytical models to handle. They are thus exceedingly useful for analyzing complicated systems in uncertain environments."[3]

Simulation models are particularly useful when it is desirable to examine a complex process operating over a long time frame. For example, it may be

3 Using Logistic Models in System Design and Early Support Planning - Rand Report R-550-PR, February 1971.

desirable to consider the maintenance workload at a tender based intermediate maintenance facility over a year's time, during which the number of ships to be supported, their electronic equipment complement and time at sea would vary on a day-to-day basis. Simulation type models would provide a picture of the workload ebb and flow, showing times of overload and times of very little workload. The results would be synthetic, i.e., they portray a situation which could occur but would most likely not be precisely duplicated in real life. There are situations, such as the work shop example, where the modeler wishes to simulate a dynamic situation in which independent variables are allowed to assume any value within a likely range.

The disadvantage is that simulation models can be costly to run because of their complexity and the user still lacks insight from the solution as to which of his parameters have the greatest impact on the system.

### 4.5.4 How Models Are Used

Although the way models are used depends on the problem or process being modelled and the characteristics of the model itself, the general procedure is the same for each application. The general procedure for using models relative to support equipment selection is shown in Figure 4-7.

In the figure, larger blocks such as "Describe Problem to be Modelled" are composed of more specific steps. The first step in describing the problem to be modelled is to define the supported equipment. As indicated on the figure, this includes such data as the prime system configuration, e.g., it is a shipboard radar composed of seven major assemblies, 36 subassemblies, and

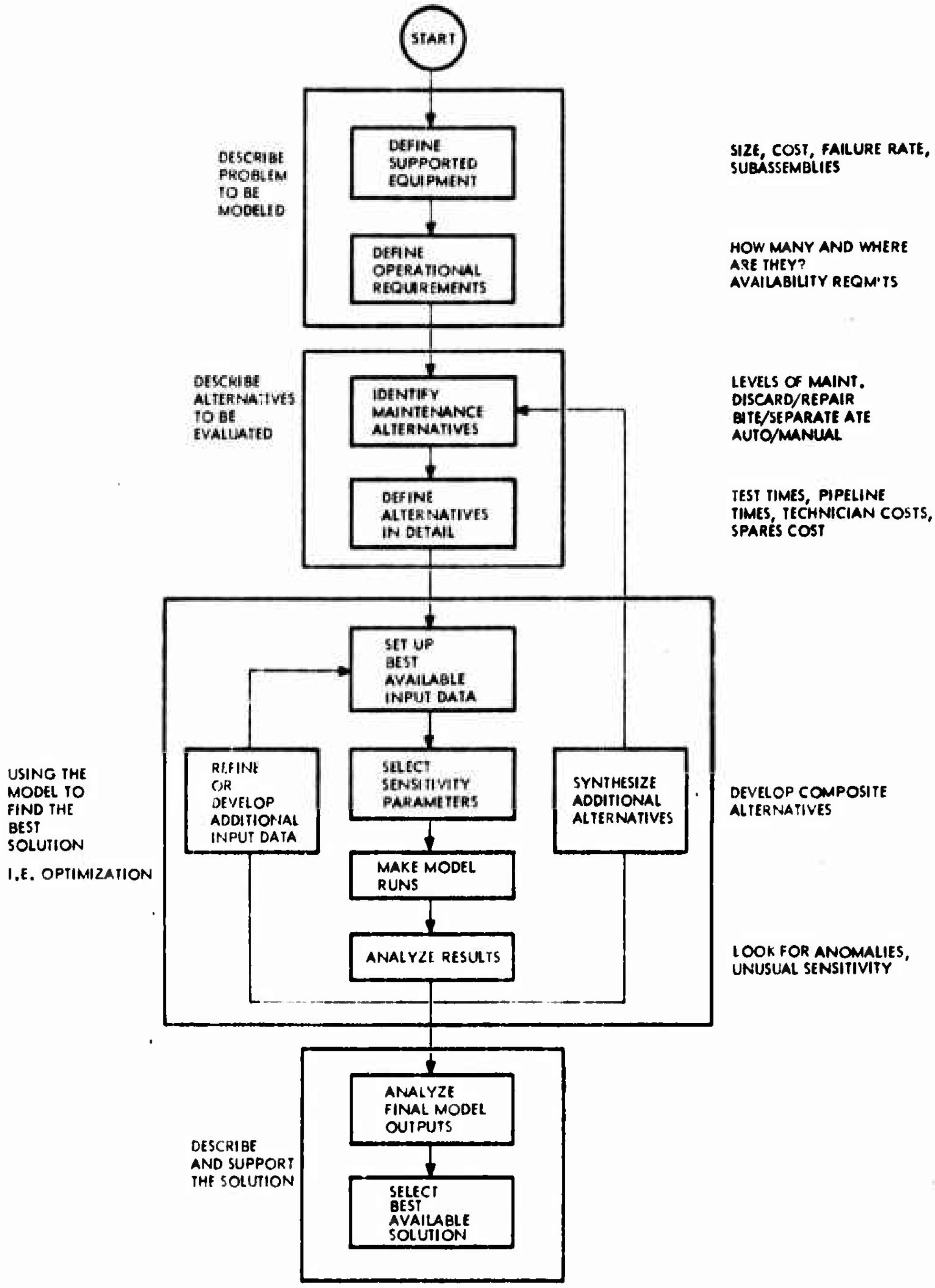



Figure 4-7. Support Equipment Selection Model

450 plug-in modules of 210 different types. Other data describing the prime system is needed including:

- Equipment breakdown
- Failure rates
- Physical characteristics
- Cost per assembly/subassembly/module
- Required availability.

Operational characteristics of the supported equipment must be defined. Operational characteristics are related to how and where the prime systems are used. This includes how many equipments are aboard ship, and the number of equipments in the fleet (if the test equipment application concerns IMA or Depot). Also needed are operational factors which determine workload, such as equipment utilization, periodic maintenance/calibration requirements, etc.

After the problem statement and descriptive data on the supported system is available, the analyst proceeds to identify the alternatives to be evaluated.

If the prime equipment is in the conceptual or advanced development phase, the alternatives are likely to be aimed at validating the support concept - to support such decisions as whether to repair modules aboard ship or off-load to an IMA, or whether to incorporate BITE in order to meet an availability requirement.

If the above examples are the nature of the decisions to be made, each alternative must be defined as though it were the chosen approach. If an alternative is using built-in test to detect failures and isolate them to a replaceable subassembly level, this approach must be synthesized in such detail that a quan-

titative solution to such effectiveness measures as "impact on availability" and "support cost" can be generated. Figure 4-7 indicates the level of data to be developed.

It is not necessary that all input data be developed or that it be extremely accurate before the first model runs are made. Many models, for example, will assume a most likely or "default" value for some input factor which is not known. Most likely values are based on experience with similar model applications.

Most models also contain format or lack of data error messages which are particularly helpful in the initial runs. In examining the initial results, the analyst looks for extraordinary values which indicate a problem in synthesizing alternatives or an unusual sensitivity to some parameter.

The next steps are an iterative process wherein the analyst examines model output, uses sensitivity outputs to narrow the contending alternatives to those which are clearly the most likely choices. If the problem is selecting a generic support equipment approach (BITE, separate automatic, separate manual, etc.) the iterative process includes reshaping the alternatives and the recommended approach is often an amalgam of two or three of the original alternatives.

The final steps focus on the selected approach, its description in detail, and presentation of the supporting data. Although the raw supporting data has been developed in previous model runs, it remains to be presented as bar charts, nomographs, trade-off and sensitivity curves which illustrate the validity of the selected approach in terms of such measures as maintenance hours, development costs, O&M costs, availability impact, etc.

If modelling is used in support of decisions to be made at entry point three in the overall Test Equipment evaluation process, e.g., which of several candidate ATE systems will best serve the fleet requirements, the alternatives are test equipment A, B, C, etc. Input data defines each equipment in terms of:

+ cost - hardware and software acquisition, operation and maintenance, etc.

+ related manpower - operation and maintenance, calibration, etc.

+ test equipment support requirements - spares, technical data, operating environment, special test equipment, software generation facilities, etc.

In all alternatives, the scenario should be the same. That is, all alternative test equipment should be compared on the same basis. Other scenarios may be used for more comprehensive comparison as long as all candidates are asked by the model to support the same workload in the same fleet environment.

In the third modelling application, the support concept is fixed, the support equipment has been chosen and the problem concerns anticipation of support resources due to some change in the present situation. Such changes would appear in the initial step of describing the problem (e.g., modification to the prime system which changes the number of assemblies) or in the second step of describing alternatives (e.g., shipboard workload has increased to where an additional test station is being considered).

The steps of iteration and refining alternatives apply here as in the other modelling applications. However since entry point three generally applies later in the acquisition cycle, there should be less reliance on default values and greater confidence in input data relative to workload, hardware costs, and man-hour information.

### 4.5.5 Input Data Requirements

The Process Being Modelled: Sometimes called the scenario, the overall maintenance process must be defined in order that the model can put the candidate support equipments in context. The model must simulate the candidate test equipment in operation as a key part of the maintenance process. Therefore, the maintenance process itself is an input requirement. The process involves material - prime equipment to be maintained, spare parts for replacing failed items, facilities or work shops in which test and repairs are to be accomplished. The process involves geography - the location of shipboard equipment, IMA, and depot facilities and logistics pipelines. The process involves time - the response time from request to receipt of a replacement, the operating time of the supported equipment, and the service life or life cycle.

Standardized Input Data: Much of the specific input data needed by the model is not unique to the problem application. There are maintenance related factors which are common to Navy logistic support. For example, costs of packing and shipping spare components need not be estimated uniquely but such numbers are available in cost handbooks. Other input data in this category are:

- Pipeline times, cost
- Personnel training time, costs, turnover
- Administrative costs associated with entering new items in supply, maintaining items in supply, requisition costs.

Historic Data: Some input information has a single value - e.g.. the cost of a repairable module may be $1200. Other input information will assume a range of values - e.g., man-hours to test and repair a unit under test. In developing

the latter information, prior experience on the same or similar equipments is sought. If the modelling application is evaluation of candidate test equipment, it should be possible to obtain historical data on test times, MTBF, etc. on the test equipment. For new equipment, design MTBFs as modified by historic data on similar equipment can be used.

Data Uncertainty: The analyst can expect, and anticipate, that he will never have firm inputs for all his data requirements. An important part of the procedure for using models is to identify quickly those factors which are most significant to his solution. This is the purpose of sensitivity analysis, where the model allows some parameter to vary through a range of values while keeping other factors constant - at their most likely value. By examining the change and rate of change of the output, the analyst can judge the sensitivity of his problem solution to the changing parameter.

An example of sensitivity analysis is shown in Figure 4-8. In this example the varying parameter is operating time fraction - the percent of real time that the supported equipment is operating. This parameter directly influences maintenance workload. The vertical axis indicates increasing costs of support, as a percentage of acquisition costs. The various curves (e.g., "Module discard") are alternatives being evaluated. It is clear that some alternatives are much more sensitive than others to changes in operating time fraction. "Unit discard" goes off scale, beyond 200 percent per year, for an operating time fraction of about 15 percent. IMA repair as a very stable alternative with little change over the entire range of operating time fraction. However, depot repair is the lowest cost policy up to about 45 percent operating time fraction. In this example, if the analyst expected that the operating time fraction would be in the 10 to 30 percent range, then Depot repair is the likely choice.

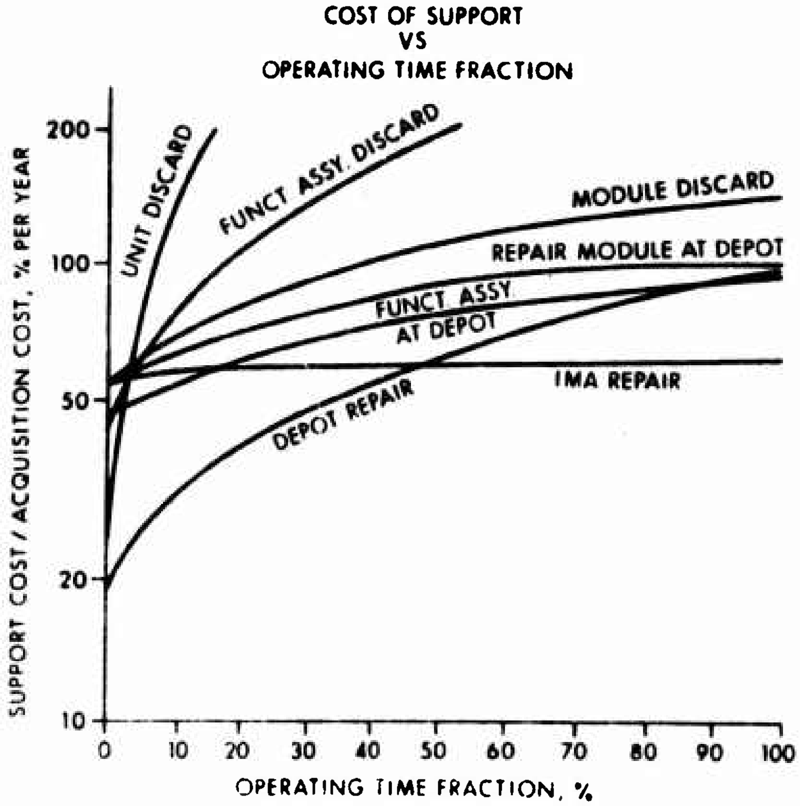



Figure 4-8. COAMP Sensitivity Testing

This example applies only to the problem for which it was derived and the analyst must resist the temptation to draw conclusions such as "IMA repair is a very stable policy". Each problem has its own solution.

Logistics related models are useful on a much broader scale than selection and evaluation of ATE. Some models are configured specifically to support decisions concerning the following:

(1) Level of repair - making a choice among alternatives as to what will be repaired and where. Repair/throw-away decisions are an example of this area.

(2) Spares - anticipation of sparing quantities and their efficient location.

(3) Personnel - anticipating operator and maintenance personnel requirements as a function of failure rates, usage rates, etc.

(4) Support equipment - determining the number and optimum location of test and repair equipment, generally in relation to prime system availability and overall cost.

(5) Life cycle cost - calculation of total cost over the life cycle with cost element visibility to indicate the impact of alternative logistic choices (e.g., location of maintenance facilities or selection of test equipment).

(6) Operations effectiveness - determining the effect on prime system operations for most likely operating environment and for potential variations.

Each logistic related model could have some usefulness in test equipment decisions, and no single model is best for every Navy application. However, there are some guidelines which will be helpful in selecting a model. "Guidelines" are general advice, usually accurate, but always subject to being subverted by an exception from time to time.

(1) Analytical models are easier to use than simulation models. By "easier" we mean that useful answers can be acquired more quickly and with significantly less computer time.

(2) Logistic models that have been used on Navy problems will have an advantage for Navy users over similar models that have not had Navy exposure. There are still differences among the services with regard to maintenance-related names and procedures, making it worthwhile to favor a model that describes input data as "test equipment" rather than "AGE" or whose readout describes "IMA cost" rather than "direct support cost".

(3) Rarely will a model be immediately available to fit precisely your problem; you can expect to do some minor adaptation. In order to adapt a good model, to decide what adaptation you really need, to most efficiently structure the input data, to make most effective the inevitable process of iterations, to do all these things the user should be able to work with an in-house systems analyst/programmer. The analyst is a bridge between the logistician (who works with levels of maintenance, operational availability, and turn-around times) and the computer programmer who thinks in FORTRAN or SIMSCRIPT and is more concerned with CPU time than system down-time.

(4) Models should not make decisions; models should support decisions made by maintenance managers.

(5) Models are most useful when they anticipate a situation before it exists. Therefore, the user must be prepared to live with uncertainties, best guesses, planning data, extrapolations from historical information, and rules of thumb. The model user should not become awed by the implied precision of five place numbers on a computer printout. He should maintain his focus on the relative effectiveness of several alternatives, not on any particular absolute value. Computers do not lie, but neither can computers discriminate between fact and fiction.

(6) Table 4-2 is taken from the Rand Report R-550-PR. It indicates the range of logistics models in use and gives some pertinent characteristics of each. Where model type is indicated "accounting" is equivalent to analytical. Since the Rand report was prepared, NADC has adapted CO-AMP for a number of Navy Applications, as shown in Figure 4-9. Figure 4-9 was taken from the forthcoming NADC Report 73240-50 "NADC Life Cycle Costing Methodology and Applications (1969 - 1973)".

# Table 4-2. Overview of the 46 Models

| Model | Source | Owner | Type | Language | Data Reqment | Application: Spares | ACF | Pers | LOR | Opns | LCC | Mgt | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACLE | Air Force Log Command | Air Force | Accounting | Joss,[d] Fortran | Minimal | | | | | | x | x | Incentive oriented |
| AMSEC | Operations Res, Inc | Opns Res | Reliability | Fortran | Moderate | x | x | x | | x | x | | System reliability |
| ARMADA | Naval Weapons Systems Analysis Office | Navy | Simulation | Fortran, Simscript[b] | Much | x | x | x | | x | x | | |
| CDSM | General Dynamics | Gen. Dyn. | La Grange Mult | Fortran | Minimal | x | | | | | | | |
| COMS | The Rand Corp | Air Force | Simulation | Simscript | Much | x | | x | | x | | | |
| CAEM | Lockheed Aircraft Corp | Lockheed | Simulation, Accounting | Fortran | Much | | | | | x | x | | Transport aircraft |
| COAMP | Radio Corp of America | RCA | Network, Accounting | Fortran | Moderate | x | x | | x | | x | | |
| DEQMAR | The Rand Corp | Air Force | Queueing | NP[c] | Minimal | | x | x | | | | | |
| CEM | Naval Applied Sci Lab | Navy | Reliability, Differential Eq | Gem, Fortran | | | | | | x | | | |
| DSS | Lockheed Aircraft Corp | Lockheed | Simulation | Fortran | Moderate | | | | | x | | | Transport aircraft |
| IPM | General Dynamics | Gen. Dyn. | La Grange Mult | Fortran | Moderate | x | | | | | | | |
| LCCM | Planning Res Corp | RCA | Accounting | Simscript | Moderate | | | | | | x | x | Costs by year |
| LCCP | Raytheon | Raytheon | Simulation, Accounting | Fortran, Cobol | Much | x | x | x | x | x | x | | |
| LCOM | The Rand Corp | Air Force | Simulation | Simscript | Much | x | x | x | x | x | | | |
| LOGCOST | Air Force Log Command | Air Force | Accounting | Fortran | Minimal | | x | x | | | x | x | Source selection |
| LORAM | Naval Air Syst Command | Air Force | Accounting | Fortran | Moderate | x | x | | x | | x | | |
| MACOM | McDonnell Douglas | Air Force | Simulation | Simscript | Moderate | | | | | x | | | Missile countdown |
| MARKS | General Electric[d] | Navy | Simulation | Fortran | Much | x | | | | x | | | |
| MCTAS | Lockheed Aircraft Corp | Lockheed | Simulation | GPSS | Much | x | x | x | | x | | | System reliability |
| MEMM | General Electric[d] | Navy | Markov chain | Fortran | Moderate | x | | | | x | | | |
| METRIC | The Rand Corp | Air Force | La Grange Mult | Fortran | Moderate | x | | | | | | | |
| MINT | The Rand Corp | Air Force | La Grange Mult | Fortran | Moderate | x | | | | x | | | |
| MRSM | Lockheed Aircraft Corp | Lockheed | Simulation | GPSS | Moderate | | x | x | x | x | | | Transport aircraft |
| OMLRS | Lockheed Aircraft Corp | Navy | Simulation | GPSS | Much | x | x | x | | x | | | |
| ORLA | Air Force | Air Force | Accounting | Fortran | Minimal | | | | x | | x | | |
| PLANET | The Rand Corp | Air Force | Simulation | Simscript | Much | x | x | x | | x | x | | |
| PROJMOD | The Rand Corp | Air Force | Differential Eq | NP | Moderate | | | | | | | x | Time cost performance |
| OCST | The Rand Corp | Air Force | Probability, Accounting | Fortran | Moderate | | | | x | | x | | |
| RAM | Naval Missile Center | Navy | Differential Eq | Fortran | Moderate | | | | | | | x | Resource allocation |
| RCM | Air Force Log Command | Air Force | Dynam Programming | Simscript | Moderate | x | x | x | x | | x | | |
| RMT | Air Force Inst of Tech | Air Force | Math Programming | Fortran | Moderate | | | | | | | x | R M improvement |
| SAMSOM | The Rand Corp | Air Force | Simulation | Simscript | Much | x | x | x | | x | | | |
| SCAM | The Rand Corp | Air Force | La Grange Mult, Accounting | Joss, Fortran | Minimal | x | x | x | x | | x | | |
| SCEET | McDonnell Douglas | Air Force | Accounting | Fortran | Moderate | | | | x | | | | |
| SCOPE | McDonnell Douglas | Air Force | Simulation | Simscript | Moderate | | | | | x | | | Missile flight |
| SCORE | Naval Air Dev Center | Navy | Accounting | Fortran | Moderate | | | x | | | x | x | Costs by year |
| SEEP | General Dynamics | Gen. Dyn. | La Grange Mult | Fortran | Minimal | x | | | | x | | | |
| SEMBRAT | The Rand Corp | Air Force | Queueing | Joss | Minimal | | x | x | | x | | | |
| SKEM | McDonnell Douglas | Air Force | Simulation | Fortran | Minimal | x | | | | | | | |
| SOGEM | The Rand Corp | Air Force | Markov Chain | Fortran | Minimal | | | | | x | | | Sortie analysis |
| SPAREM | General Dynamics | Gen. Dyn. | Simulation | Simscript | Moderate | x | | | | x | | | |
| SPARTAN | The Rand Corp | Air Force | Network | Fortran | Moderate | | | | | | | x | Development sched |
| SPM | Lockheed Aircraft Corp | Lockheed | Algebraic | Cobol | Minimal | x | | | | | | | Transport aircraft |
| SSM | General Dynamics | Gen. Dyn. | Simulation | Simscript, Fortran | Moderate | | x | x | | x | | | |
| TRIM | Raytheon | Army | Accounting | Fortran, Cobol | Moderate | x | x | | x | | x | | |
| VALUE | Martin Marietta Corp | Navy | Simulation | GPSS | Much | x | x | x | | x | x | | Aircraft carrier |

[a] Joss is the trademark and service mark of The Rand Corporation for its computer program and services using that program. [b] Simscript or Simscript 1.5. Simscript 1.5 is a trademark of Consolidated Analysis Center, Inc. [c] Not programmed. [d] Tempo Division.

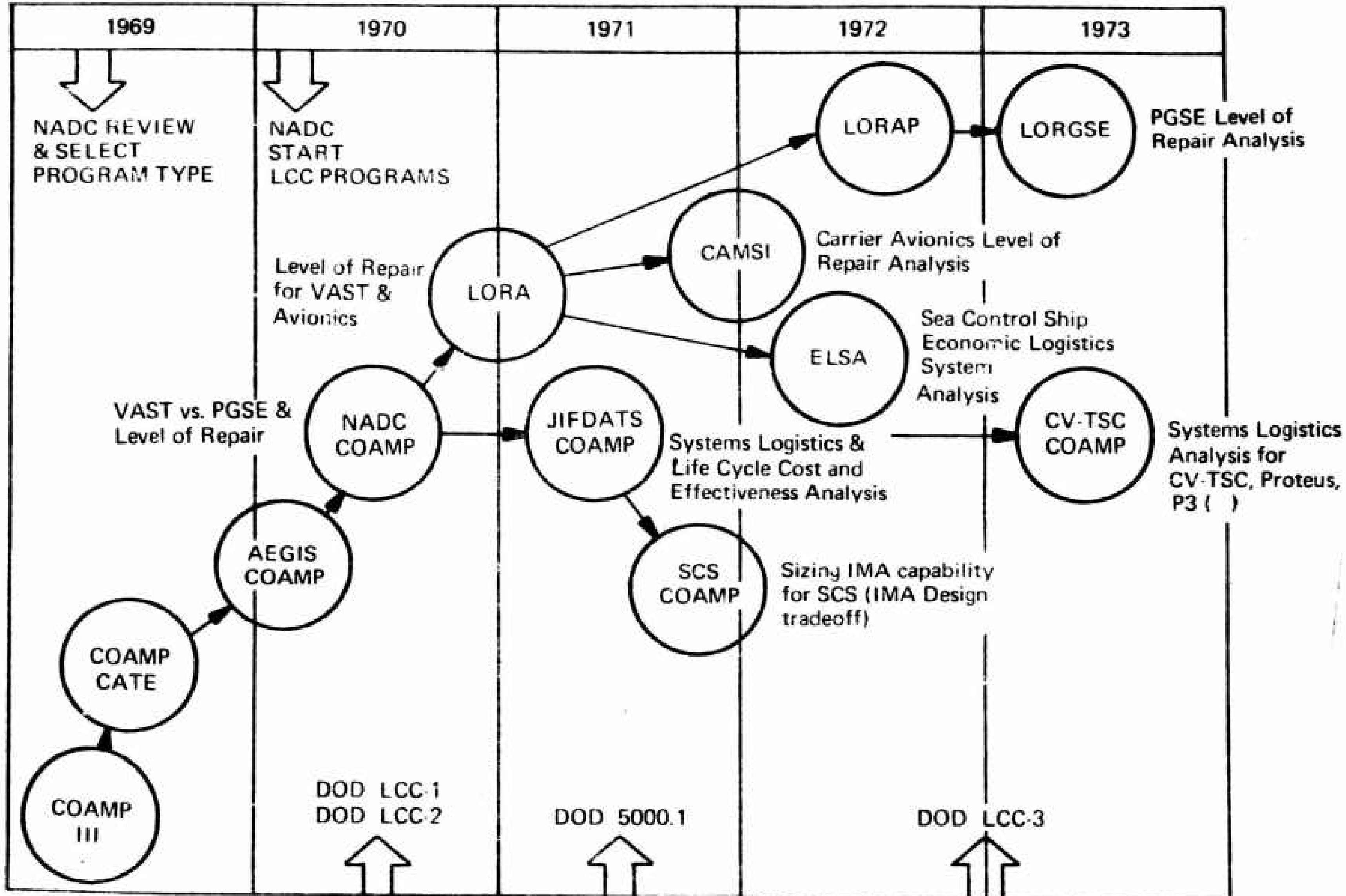



Figure 4-9. Principal Model Applications During the Evolution of NADC Life Cycle Cost Methodology

## 4.6 A BUILT-IN TEST EVALUATION MODEL (BITEM)

### 4.6.1 Background

When designing BITE for a system as extensive as a tracking radar or missile control complex, achieving fault isolation uniformly to a single module or within a fixed number of modules is difficult. Circuit partitioning for such a system must trade standardization against ease of fault isolation, and while logistic considerations govern on either side of the trade, the benefits of maximum standardization can justify accepting less than ideal BITE performance. This occurred on AEGIS, where a supplementary off-line module tester will be used to locate the faulty modules in a group identified by ORTS (ref. Paragraph 3.1.4) as containing one or more such modules. It is desirable to be able to measure the performance of a proposed BITE configuration, especially when compromise alternatives require evaluation. The scheme to be described herein was devised for that purpose. It is the outline of a model for measuring the results of BITE with regard to how closely it approaches the ideal of fault isolation to every single module in an equipment, and comparing that performance to its cost. Although intended for evaluating BITE, a similar technique could be applied to other forms of test equipment.

### 4.6.2 Approach

The BITEM approach consists of developing a number which represents the summation of weighted benefits to accrue from a proposed configuration, and then evaluating the benefits against the costs to achieve them. It is suggested that life cycle costs should be used, although limitation to acquisition costs is not excluded. The expression for benefits consists of the algebraic summation of weighted benefit evaluation factors. Some benefits are difficult to evaluate

numerically with precision, and a 0-4 scale could be adopted for those cases. Also, there are negative "benefits" such as complexity, size and power increases due to BITE which are subtracted from positive benefits. Of course, the negatives would go positive in the unlikely event that BITE should result in reducing any of these factors. Net negative benefits would result in rejecting the proposed configuration. All BITE benefit evaluators will consist of a number which represents the extent of the benefit, multiplied by a weighting coefficient which may vary from application to application, depending upon the relative significance of each benefit to the particular application.

Costs require no weighting and are naturally evaluated. Costs incurred are positive; cost savings are negative. Table 4-3 lists benefit and cost factors. Factors are self-explanatory, but will be further enlarged upon later in this section. Table 4-4 reduces the English language terms to a mnemonic format.

Table 4-3. Built-In Test Evaluation Model (BITEM) Factors

| | | |
|---|---|---|
| Benefit | = | A(Performance) + B(Availability Increase) + C(Flexibility) + D(Growth Capability) + E(Man-Machine Interface) - F (Prime Equipment Complexity/Size/Power Increase) + G (Operational Safety Improvement) + H(Mission Assurance) |
| Cost (Life Cycle) | = | (Acquisition Cost Increase) + (Support Cost Increase) - (Saving in External ATE Hardware Acquisition and Support) - (Saving in External ATE Software) - (Saving in Prime Equipment Maintenance and Spares) |

Evaluation factors are in parentheses; those for benefits should be scored.

Benefit weighting factors are coefficients A-H.

Table 4-4. Built-In Test Evaluation Model (BITEM) Mnemonic Terms

| | |
|---|---|
| Benefit | $= A(PERF) + B(A_O) + C(FLEX) + D(GROWTH) + E(ITF) - F(COMPLEX) + G(SAF) + H(MSN)$ |
| Cost | $= \Delta ACQ + \Delta SPT - \Delta XTE - \Delta XSW - \Delta LOG$ |
| Figure of Merit | = Benefit/Cost |

### 4.6 3 Benefits

Table 4-5 tabulates and defines the benefit factors. An attempt at numerically evaluating test performance will be discussed later. The availability factor naturally lends itself to numerical treatment, as do complexity, size and power increases. Flexibility, growth capability, man-machine interface, operational safety improvement, and mission assurance are not so easily evaluated, and discrete steps are suggested for that purpose. A scale of 0-4 could be used to rate the degrees to which these benefits are in evidence. The numbers 0-4 would be equivalent respectively to none, poor, fair, good, excellent.

Table 4-5. BITEM Benefit Evaluation Factors

Performance
Score for fault isolation level, number of modules, on-line, off-line.

Availability Increase
Desired prime availability will be specified. Scoring will be negative for availability below specification; positive above. Weighting for availability above specified will reflect desirability of improvement.

Flexibility, Growth Capability
Flexibility for other applications, growth scored on ease of expansion.

Man-Machine Interface
Score for operational convenience, quality of displays.

Table 4-5. BITEM Benefit Evaluation Factors (Cont.)

| |
|---|
| Prime Equipment/Size/Power Increase (May be Three Separate Factors)<br>Scoring directly proportional to increases. Sign changes if decrease achieved. Weighting significant for aircraft, submarine applications. |
| Operational Safety Improvement<br>Where safety not a consideration, weighting can be zero. For flight applications it could be dominant factor. |
| Mission Assurance<br>Similar to operational safety. |

4.6.4 Costs

Table 4-6 tabulates and expands on cost factors. The addition of BITE will increase acquisition cost as it increases overall equipment complexity. Support costs will also rise proportionally as an incremental increase in spares, maintenance, and documentation. BITE could eliminate or reduce the cost of external ATE support in hardware, software, and operational and maintenance areas. Depending on the level of fault isolation achieved, maintenance manpower and spares costs could be reduced on the prime equipment.

Table 4-6. BITEM Cost Factors

| |
|---|
| Acquisition, Support Increases<br>Estimate as proportion of prime in absence of firm data. |
| Saving in External ATE Hardware<br>Estimate life cycle costs of external ATE hardware eliminated by BITE. |
| Saving in External ATE Software<br>Estimate saving in software that would have accompanied above ATE hardware. If ATE hardware available at no extra cost (e.g., vast on carrier), estimate software saved by not having to use vast. |

Table 4-6. BITEM Cost Factors (Cont.)

| |
|---|
| Saving in Prime Equipment Maintenance and Spares<br>Estimate saving in maintenance manpower. If increase, rather than saving, change sign. Estimate saving (or increase) in support spares. |

### 4.6.5 Performance Benefits

A major benefit is that of BITE performance in the areas of monitoring and fault isolation. An attempt has been made in BITEM to evaluate this factor. BITE performance, particularly for systems, is often a series of compromises with the ideal, and a method has evolved in BITEM to evaluate those compromises. An abstract example is shown, consisting of six modules (or components, or assemblies), which represents the desired level of fault isolation by BITE. Although it is preferred that BITE will isolate faults to any one of these six modules, it is recognized that technical limitations or prime equipment constraints may make this unfeasible, and that faults may be only isolated to groups of modules in some cases. Figure 4-10 shows the interrelationship of the six modules. Dotted lines enclose the fault isolatable groupings. It is assumed that only one grouping at a time will fail or be fault isolatable. This is not an immutable law, but it does represent the usual practice with BITE, which makes maximal use of the still operational portion of the system to test the remainder.

Table 4-7 lists the scoring rules. The modules are rated in complexity on a scale of 1-4 and are scored accordingly. To avoid a lengthy study on the distribution of components and individual component reliabilities, this could be accomplished by simply counting parts. (Common sense would, of course, recognize and suggest ways of handling an extreme case such as a module full

of resistors.) Locating a fault to any individual module would then provide a score of 1-4.

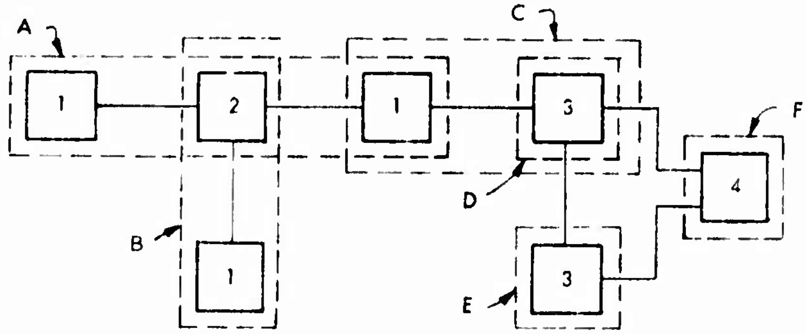
Table 4-7. Sample Scoring Procedure

| |
|---|
| Performance |
| Rate modules by complexity from 1-4. |
| Score 1-4 for each individual fault isolatable module. |
| Where modules are fault isolated as groups, totalize complexity numbers in group, and divide by number of modules in group. |
| Where fault isolatable groups overlap, score common modules only in the smallest of the groups in which they appear. Use the actual module count as a divisor for the complexity total of the remaining modules. |
| Use multiplying factor of 1 for off-line, 3 for on-line, or weight to suit. |

Fault isolatable groups would be scored by totaling the scores of all the modules in that group and dividing by the number of modules in the group. Where groups overlap, common modules are scored only in the smallest group in which they appear. However the scoring divisor for any group will always consist of a count of all modules in that group regardless of where else individual modules may be scored.

Because on-line fault isolation (non-interfering with normal operation) is more desirable than off-line (interfering with or interrupting normal operation), a weighting coefficient of 3 is assigned to on-line fault isolation. This is an arbitrary figure which can be varied to suit the particular application.

The example of Figure 4-10 assumes all off-line testing. Group A illustrates the scoring method. Its module score is 4 reduced by 3 because of two common modules which are scored in groups B and C, respectively. The division of 3




| | COMPLEXITY SCORE | DIVISION | PERFORMANCE SCORE |
|---|---|---|---|
| GROUP A | (4-3) = 1 | 3 | .33 |
| B | 3 | 2 | 1.50 |
| C | (4-3) = 1 | 2 | .50 |
| D | 3 | 1 | 3.00 |
| E | 3 | 1 | 3.00 |
| F | 4 | 1 | 4.00 |
| | | | 12.33 |

MAX. POSSIBLE SCORE = 15

Figure 4-10. Example of Performance Scoring

for the number of modules in Group A results in a group score of 1/3, or 0.33. The maximum total score possible would have been 15, the sum of all individual module scores. However, group reductions resulted in a score of 12.33.

This model is not concerned with the fault isolation logic or method, or with the mix of hardware and software except as it affects cost. It was intended to provide a much-needed means for numerically scoring only the results achieved by BITE.

There are possible ambiguities in the scoring, and the model can be manipulated to exploit them. For example, although it might be possible to do without Group C in a real-life case, and with a possible software saving at that, its

retention could be motivated by the increase in score from 11.83 to 12.33, although the cost should go up to reduce or eliminate the advantage. Clearly, this model, in common with many others, does not entirely eliminate the need for human judgment.

# SECTION 5
# ILLUSTRATIVE EXAMPLES

## 5.1 ACQUISITION PHASES

In this section will be presented examples of how the procedures previously described can be applied during each acquisition phase. Case histories are used to demonstrate the importance of timing and the interdependency of the ILS and the ATE definition processes.

No ATEs were available as examples which were acquired under the new acquisition phase terminology of NAVMAT INST 4000.20A. Instead, the terms Contract Definition, Design and Development, Engineering Development Model, Production, and Inventory will appear, except in subsection headings where the new terminology is used. Equivalences follow.

| Old | NAVMAT Inst 4000.20A |
|---|---|
| Concept Formulation | Conceptual |
| Contract Definition (CD) | Validation |
| Design and Development (D+D) | Full Scale Development |
| Engineering Development Model (EDM) | Full Scale Development |
| Production | Production |
| Inventory | Deployment/Operational |

No example is given for the Concept Formulation/Conceptual Phases. On AEGIS it was observed that as far as test systems were concerned, the Navy preferred

to state prime system requirements and allow each competing contractor a free hand in proposing the means for meeting specified availability and maintenance policies. Then the Navy evaluated the proposals and thus selected the ATE approach. For the Conceptual Phase of large systems, such as AEGIS, this seems more desirable than the Navy's specifying the ATE system, because it encourages creativity in contractors and gives them the total responsibility for system support. For smaller individual equipments, such as radios, which may be applicable to a variety of system configurations - aircraft, surface ships, submarines, land bases - and which may be supported by different logistic policies in each environment, it is recommended that the Navy specify the generic ATE. The Navy is in a position to be more aware than the contractor of the possible range of future applications and logistic support policies. For radios and similar equipments BITE will increasingly be specified as the generic ATE, and the contractor's role will consist of striving to maximize the benefit-cost ratio of the BITE design.

### 5.1.1 Validation Phase

Introduction: The AEGIS, Mark 7 weapon system contains an on-line test system, the MK 545 Operational Readiness Test System (ORTS), and its selection followed the procedure described in this report. This example illustrates the ease with which ATE selection decisions can be made when prime equipment, test equipment, and logistic specialists work together, and when trade-off decisions are simplified by a few overriding evaluation factors.

Three contractors were selected by the Navy for the Contract Definition Phase (now Validation Phase). The single contractor selected to design and build the Engineering Development Module, had chosen as the generic ATE type an integral on-line system, in response to availability and maintainability factors which

were specified by the Navy, based on operational mission requirements. The ATE selection procedure was therefore performed by the contractor in this case, with Navy approval clearly implied by review and acceptance of the proposal. After contract award, the Navy program office continued to contribute to the design decision process by means of design reviews.

Description of AEGIS: The AEGIS weapon system includes AN/SPY-1 multifunction radars, illumination radars, and Mark 26 missile launchers. The AN/SPY-1 radar uses an electronically scanned phased array antenna with individual element drive amplifiers.

The illumination radars use mechanically steerable antennas. The Mark 26 launcher is digitally controlled for automatic selection, load, and reload of the missile types (anti-air or anti-submarine) required. Illumination radars and missile launchers had already been developed when the AEGIS program was initiated. The AN/SPY-1 development was initiated with the AEGIS go ahead. Therefore, the test system had to accommodate a mix of test philosophies, since redesign for a uniformly centralized system was economically unfeasible.

The ATE Selection Procedure: The first block in Figure 4-1 is establishment of support requirements. This was done by the Navy. During the competitive CD Phase, RCA, the winner of the EDM phase, synthesized alternative support concepts and evaluated them against availability and maintainability parameters developed by the Navy. Test equipment alternatives at the generic level were also synthesized. The extent of the installation - solid-state equipment compactly packaged in dozens of racks, cabinets, or consoles located on several decks - eliminated manual testing from serious consideration because of the near impossibility of providing the high degree of test access and skilled manpower which would have been called for. Off-line ATE, except for modules, was out

of the question because of the set-up time and because economies were indicated in the ability of an integral on-line system to use self-generated stimulus and other portions of the AEGIS system for self-test purposes. It very quickly became apparent that availability and maintainability goals required an immediacy in status reporting and fault diagnosis that could only come from an automatic on-line test system.

Also, the system was designed for "graceful" degradation. Individual antenna element drivers could fail with some degradation of the antenna pattern, but without seriously jeopardizing overall operation. It was essential for the operator to be aware of that condition, so that the mission could be modified if necessary, or corrective action undertaken. Data on existing systems of comparable complexity reinforced this decision. It was clearly impracticable for the on-line system to fault isolate to better than a module or group of modules, so that an automatic module tester was indicated to hold on-board spares and maintenance manpower to reasonable levels. So far, it is seen that the decision process was straightforward, because there never were any serious competitors to the alternative of automatic on-line test with an off-line module tester for back-up.

### 5.1.2 Full Scale Development

Introduction: Following evaluation of Contract Definition Phase results, the contract for the Engineering Development Model was awarded to RCA. The ATE selection procedure now stood at point 2 on Figure 4-1. The support concept and generic ATE types were defined.

Detailed Test Requirements: Enough preliminary design work was done during CD to define test requirements in a general way. An estimate was made at

that time of the number of test points required in order to define the configuration and cost of the proposed ATE. During design, test requirements were developed in detail to enable the test equipment hardware and software to be better defined. To accomplish this, it was necessary to make test logic design a formal part of the equipment design process. Otherwise, the normal technical and schedule pressures would have relegated the test requirements to a low priority and to possible neglect. The equipment designers were, by program procedure, required to locate test points and design the test logic which showed how the test points were going to be used and what the logic was going to accomplish. Signal conditioners required to meet the ATE interface were also identified. This information was documented to a predetermined uniform format and reviewed for conformance to status monitoring and fault isolation goals. The review groups consisted of a mixed panel of prime equipment design personnel and ATE systems engineers. For future programs the review panel could as easily be composed of, or include TETSO or other Navy representation, with steps taken to ensure rapid turn around where the need is identified for changes. The same discipline was exerted on the subcontractor who was designing the AN/SPY-1 radar transmitters.

Selecting the ATE Configuration: The steps that begin with entry point no. 3 in Figure 4-1 are described here. The comparison of ATE capability to test requirements is performed by the prime equipment designer, since the stimulus requirements will be supplied by his own equipment, and the measurement interface will already have been defined for him as part of the generic ATE description. The reference to a data bank for on-line or built-in test consisted of examining existing data multiplexing and transmission methods and hardware, and that task was performed by the ATE systems engineers. The candidates for that purpose were evaluated by the ATE systems engineers on the basis of technical, maintainability, risk, and cost considerations.

For the AN/SPY-1 radar the selection process was straightforward because the radar and the ATE were designed together. The illumination radars and missile launchers were already in existence with their own integral test provisions, and that test data had to be integrated into the overall ATE system, which eventually was designated the MK 545 Operational Readiness Test System (ORTS). The alternatives presented were to modify the illuminators and launchers into a uniformly centralized test system or to use the status data internally generated by them in the best way possible with no modification. No formal trade-off was required to eliminate the first alternative, at least for the Engineering Developmental Mode. The cost of the extensive changes that would have been required did not justify the technical advantages that would have been achieved. Status panels were integrated into the ORTS Test and Monitor Console, which contained indicators driven by the illumination radars' internal status monitoring devices. The launchers contained integral status panels which, it was decided, would continue to be used in place, with possible addition of ORTS data collection provisions only in subsequent models. The data processing subsystem was based on standard Navy AN/UYK-7 computers which depend largely on self-test software for fault indication. Control of self-test software is centered at the ORTS Test and Monitor Console to permit rapid reconfiguration and load transfer in the event a computer is down. There was a protracted period of decision-making which involved selection of the detailed means for implementing ORTS goals. Alternative data transmission methods and devices were examined. Decisions were required in the configuration and placement of data collection devices. This detailed selection process consisted largely of comparing technical performance, risk, operating flexibility, and cost of alternatives.

Figure 5-1 is a simplified block diagram of the selected concept. The data transmission method uses a data bus with a serial digital data format. Where parallel data must be sensed, it is collected in parallel and stored at data collection terminals for later serial transfer. The transmission system selection criteria included cost, accuracy, ease of installation, noise immunity, error detection, and EMI generating considerations. The data collection interface selection was influenced by the Navy's MIL-STD-1326 ATE interface specification. All analog signals are conditioned and normalized to a standard dc range for conversion to the digital transmission format at the data collection terminals. Digital signals are collected serially or in parallel, synchronously or non-synchronously. The signal conditioners are designed as modules which

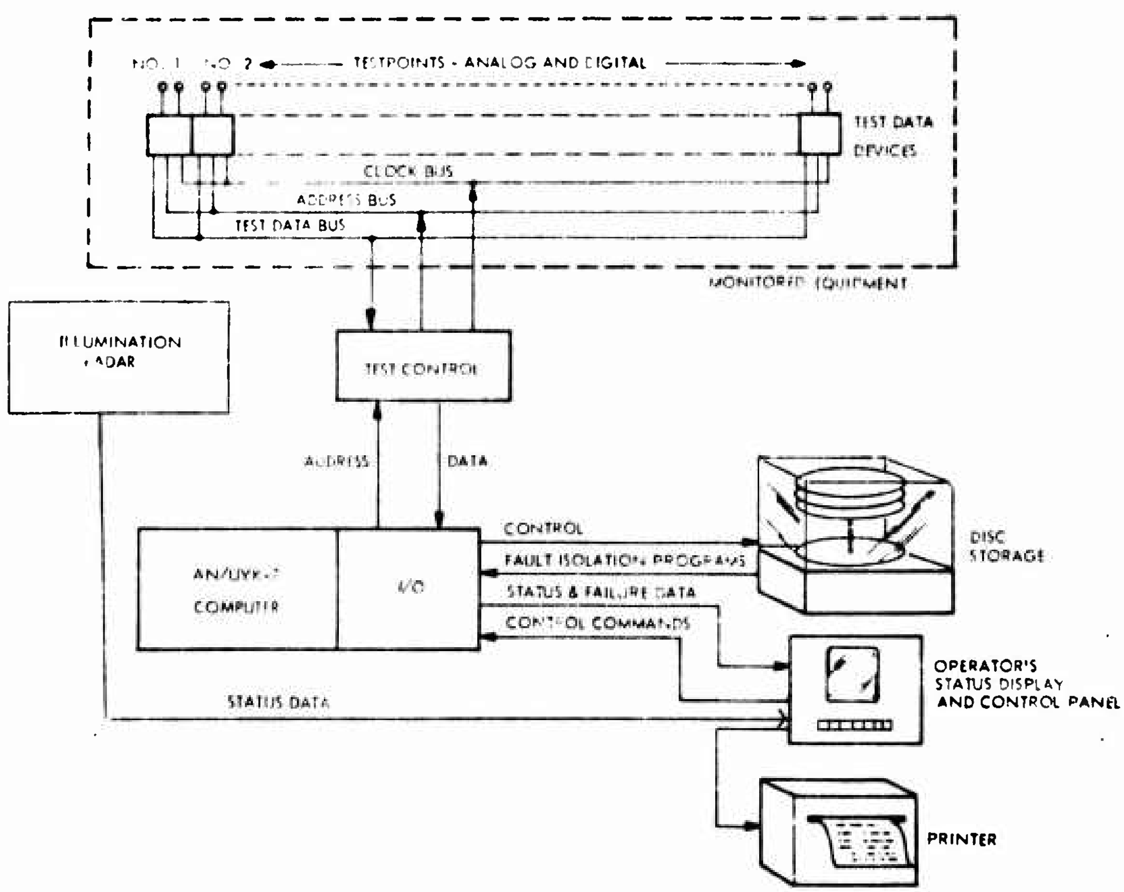



Figure 5-1. Mk 545 Operational Readiness Test System (ORTS) Block Diagram

are interspersed with prime equipment modules. The data collection terminals are separate standard assemblies located in prime equipment cabinets and housing A/D data point address recognition and transmission devices. Data from each test point is transmitted on command from the AEGIS central processor. ORTS utilizes a shared input/output line from an AEGIS AN/UYK-7 computer.

Since the ATE and prime equipment were developing together, an ATE configuration had to be selected which could accommodate changes in the prime system. Flexibility and ease of expansion were, therefore, heavily weighted evaluation factors. The data collection terminals are readily expanded or contracted to accommodate subsequent design changes or other applications, and the data interface was standardized early in the program to ensure compatibility of ORTS and prime equipment designs.

Another area of decision was the fault isolation depth to be selected. Projected design cost, technical risk, and complexity increased as fault isolation approached the single module level. In the other direction the logistic advantages of ORTS diminished as the number of modules in a fault-isolated group arose. A compromise was effected wherein a fault isolatable group would consist of an average of 5 modules. The eventual deployment of a module tester with operational models will enable rapid isolation of the faulty module in a group.

5.1.3 Production Phase - Hughes Aircraft Corp.

5.1.4 Inventory Phase - Hughes Aircraft Corp.

5.2 TRANSCEIVER - Hughes Aircraft Corp.

## 5.3 INTEGRATED RADIO ROOM

### 5.3.1 Introduction

The Integrated Radio Room (IRR) is similar to the AEGIS system in its heterogeneity, but considerably smaller in scope. Concept design was performed by the Navy, and the stringent logistic and manning considerations of the submarine environment clearly pointed to an on-line automatic test system. As its title implies, it is an integrated communications center, and control is automated and centralized to the extent practicable. Since communication processing requirements could be satisfied only by a computer, the opportunity presented itself for a relatively sophisticated Control, Monitor and Test system (CMT), without unduly complicating the overall system, by shared use of one of the communications control computers. This discussion will be limited to the Monitor and Test portions of that system, which are the areas of interest of this report and which do not involved classified items in the system.

### 5.3.2 ATE Selection Procedure

The Navy had already made the generic ATE decision based on availability, maintainability, and manning constraints, so that the contractors (three were selected for design, two for prototype construction) were started at point 2 of Figure 4-1. The selection process was therefore centered on means to implement the generic configuration selected by the Navy. Widely different test philosophies had to be accommodated because of the fact that economics dictated that existing developments be used if technically acceptable. The major evaluation factor was cost, and a very strong case had to be made for any technical benefit which raised cost. This is understandable, because an Integrated Radio Room is already basically more expensive to buy (although not necessarily to

own) than the conventional radio room, because of the additional cost of the integrating elements over that of the communications gear alone.

Details of the selected configuration will be omitted from this discussion because the CMT is essentially a computer-controlled multiplexed information data bus similar to the AEGIS ORTS. More pertinent to this report was the necessity to depart from automated and centralized testing where the benefits were not justified by the added cost. This example demonstrates that formal trade-offs are not required for decisions involving on-line ATE when the desired alternative is obvious, based on some dominant evaluation factor - cost, in most cases.

<u>VLF Subsystem</u>: The Very Low Frequency (VLF) subsystem contains its own signal processing equipment which includes sufficient data processing capability to perform internal status monitoring and testing. Allowing VLF test to be a built-in function saved the cost of the interface that would have been required if test functions had been externally implemented. The interface provided is reduced to that necessary to enable overall control from the CMT Console and to transmit status information to the CMT Console. This subsystem is the most complex and it has the highest utilization rate of any submarine communication equipment. It was designed especially for the IRR. Therefore, there was a clear-cut justification for built-in comprehensive automatic testing.

<u>LF Radios</u>: The Low Frequency (LF) radios are standard AN/WRR-3s. No automatic or remotely indicated test provisions are included. However, the use of two radios offers some redundancy, and the cost of a major redesign to include either built-in test or an interface to permit external on-line testing could not have been justified.

HF Subsystem: The High Frequency (HF) Subsystem includes three receiver/exciters, one power amplifier which is connected to one of the receiver/exciters, and an auxiliary receiver. All except the auxiliary receiver are components of the MK LC HF transceiver system described in Section 3.1.3. The auxiliary receiver has no on-line test provisions; the others use BITE. Constant parameters, such as power supply and synthesizer outputs are continuously monitored internally and on-line, in a one-second automatic sequence. When one of those parameters fails, the number of the faulty module is indicated. A sequential automatic test of all modules can be run by momentarily taking the receiver/exciter and associated power amplifier off-line. When a fault is detected, an indicator displays the identification number of the faulty module. The power amplifier is tested with the receiver/exciter to which it is connected. The module test can be initiated either at the equipment, or by command of the CMT computer. The selection of this alternative was influenced by the cost advantage and the lack of technical risk in accepting a method which had already been designed and proved. The designers of the HF equipment selected the BITE approach because the availability internally of suitable stimulus signals made possible comprehensive on-line fast-operating testing which caused no significant increase in equipment complexity and cost. An interface to enable external on-line testing would have been more complex and costly than the BITE devices. An off-line test set would have increased MTTR, and lowered availability.

UHF Subsystem: The Ultra-High Frequency (UHF) subsystem includes one AN/WSC-3 transceiver. Like the HF units, constant parameters are continuously and automatically monitored, including phase lock loop voltage, oven operation, oscillator and power supply outputs. However, fault indication is provided by a single light which glows when any one of these parameters is faulty. Further built-in tests are manually initiated and sequenced by a rotary switch on the equipment panel. Results are read on a go/no-go meter. Cost was the

dominant evaluation criterion which led to acceptance of the combination of automatic and manual testing built-in to the AN/WSC-3. Although the test approach is operationally less convenient than that of the HF radios, availability goals are adequately met, and a costly redevelopment was avoided.

Subsystem Auxiliaries: Interconnection of antennas, multicouplers, and peripheral devices is computer-controlled, and the interconnections are automatically monitored. The alternative of manual patching and verification by inspection was entirely incompatible with the concept of an integrated radio room and was, therefore, eliminated in earlier Navy studies. Computers are all self-tested by software.

## SECTION 6
## APPENDIX[1]

### 6.1 EVALUATION FACTORS

This section contains a listing of evaluation factors for use in comparing ATE alternatives. It is possible to develop evaluation equations by assigning values and weighting each factor. Weighting will depend on individual applications and may contain a high degree of subjectivity. Cost factors can be used without any manipulation, and rough benefit/cost ratios can then be developed by dividing the summation of weighted benefits by cost for each alternative. Evaluation factors may be used individually for screening purposes, eliminating ATE candidates for such reasons as being too large for the available space, too costly for the available funds, or incapable of meeting environmental requirements. Figure 6-1 summarizes evaluation factors and the methodology for their use. Evaluation is seen as a sometimes iterative process, wherein compromises in ATE requirements may be compelled by technical and fiscal realities.

#### 6.1.1 Technical Factors

Technical evaluation factors are useful for initial screening purposes. Later in the evaluation process, if otherwise attractive candidates are identified which do not quite meet all technical evaluation factors, then technical factors may be assigned values and weighted for use in a trade-off process. The high cost of militarized equipment, for example, is resulting in serious consideration being given to the previously unthinkable prospect of shipboard installation of ATE designed to best commercial standards.

[1] Parallel tasks were assigned to Hughes Aircraft Corporation for those described in Sections 6.1 and 6.2.

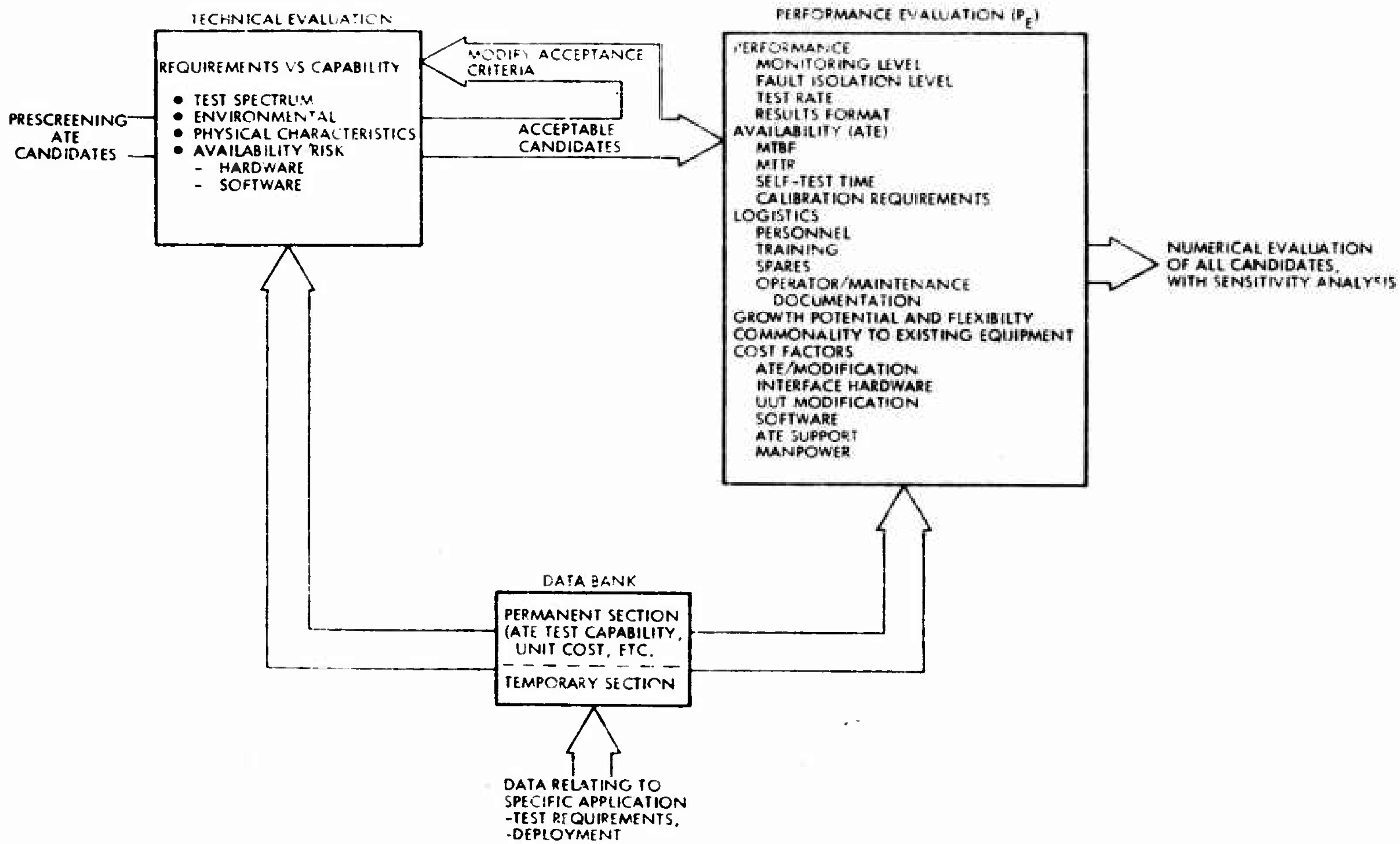



Figure 6-1. ATE Evaluation Methodology

Test Spectrum: From an analysis of prime equipment test requirements, a spectrum is generated of test stimuli and measurements. From this listing a data bank can be scanned for candidates in existing inventory.

Environmental: Although the acceptability for military use of high grade commercial ATE is growing, there are still applications which demand design to the more stringent MIL environmental requirements. Environmental specifications are, therefore, an important technical evaluation factor.

Physical Characteristics: Space, weight, power, and cooling requirements are typical physical characteristics to be evaluated.

Availability/Risk: The extent to which candidates are available, or the risks of developing new ATE are factors to be considered. There is even a risk in re-procuring previously designed ATEs if not presently in production, in that a significant start-up cost could be encountered or technological obsolescence could make components difficult to procure. Available software versus the risk of developing new software must be considered in view of the length of time and cost to develop software.

### 6.1.2 Performance Evaluation Factors

Some performance evaluation factors are also technical in nature but at a system level, and are therefore treated separately from detailed technical evaluation factors.

Performance: Measures of ATE performance are monitoring and fault isolation levels, test rates, and results formats. For some applications, the allocation of on-line and off-line test tasks may also be of significance.

Availability: Availability evaluation factors for the ATE involve MTBF, MTTR, and calibration requirements. Consideration is required of the level and speed of self-test, and the relative degree of in-place calibration vs. calibration requiring component removal.

Logistics Factors: Logistics factors are at least as important for the ATE as for the equipment it supports, since prime equipment availability can depend heavily on its ATE. Logistic factors consist of personnel, training, spares, calibration facilities, and support documentation. Operational and maintenance crew size and skills need to be identified. When tests will call for operator intervention in the test cycle, as often encountered with off-line IMA and depot testing, the operator may need training in UUT as well as in ATE operation. Spares levels, locations, and pipeline times are significant factors. The location of the calibration facility (if needed) and any special equipment for that purpose should also be identified.

Growth Potential and Flexibility: These factors break down into excess technical requirements and capacity, and design flexibility. The evaluator must decide what these factors are worth to him, and to do so, he has to estimate future needs. Technical requirements in excess of presently known needs may be sought to handle additional UUT types, or in anticipation of possible design changes to existing UUTs. Excess test rate capacity may be desirable to allow for UUT operational MTBFs which may be lower than predictions, or in anticipation of additional support requirements from other causes, or simply, as a conservative allowance for ATE or personnel performance which may not come up to expectations. Flexibility of design is related to excess technical requirements. It is desirable as a means for avoiding early obsolescence, and to meet supported system changes. Flexibility of design

will facilitate establishing expanded or contracted configurations to serve a variety of applications from one design family.

Commonality Factors: Related to logistics and flexibility factors are commonality factors. It is clearly desirable for an ATE to use a minimum of newly designed assemblies. The ATE could use assemblies from another ATE or from the prime equipment, as in the so-called "hot mock-up" type of special test sets.

Cost: Cost factors dominate any ATE evaluation, and will continue to do so. Costs go beyond the ATE itself and can be significant where supported equipment must be modified for compatibility with the ATE. It has become well-known through disillusioning experience that software costs can exceed hardware costs in some applications. As with any other equipment, documentation costs for ATE can also be significant. Acquisition costs and life cycle costs may have to be separately considered. Figure 6-2 tabulates a hierarchy of items that make up total ownership costs, and Figure 6-3 separates acquisition, application, and usage costs. A listing of cost factors follows:

ATE Acquisition/Re-acquisition/Modification Cost: Is new ATE to be required? Existing ATE to be re-acquired? (Beware start-up and inflationary escalation.) Can existing ATE be used or re-acquired with modifications to do the job?

UUT/ATE External Interface Hardware: These are the adapter boxes and cables used between UUTs and ATE. Although potentially a costly item (and a storage and retrieval problem), it is usually far less costly than to alter the UUT and the ATE to eliminate the need for them.

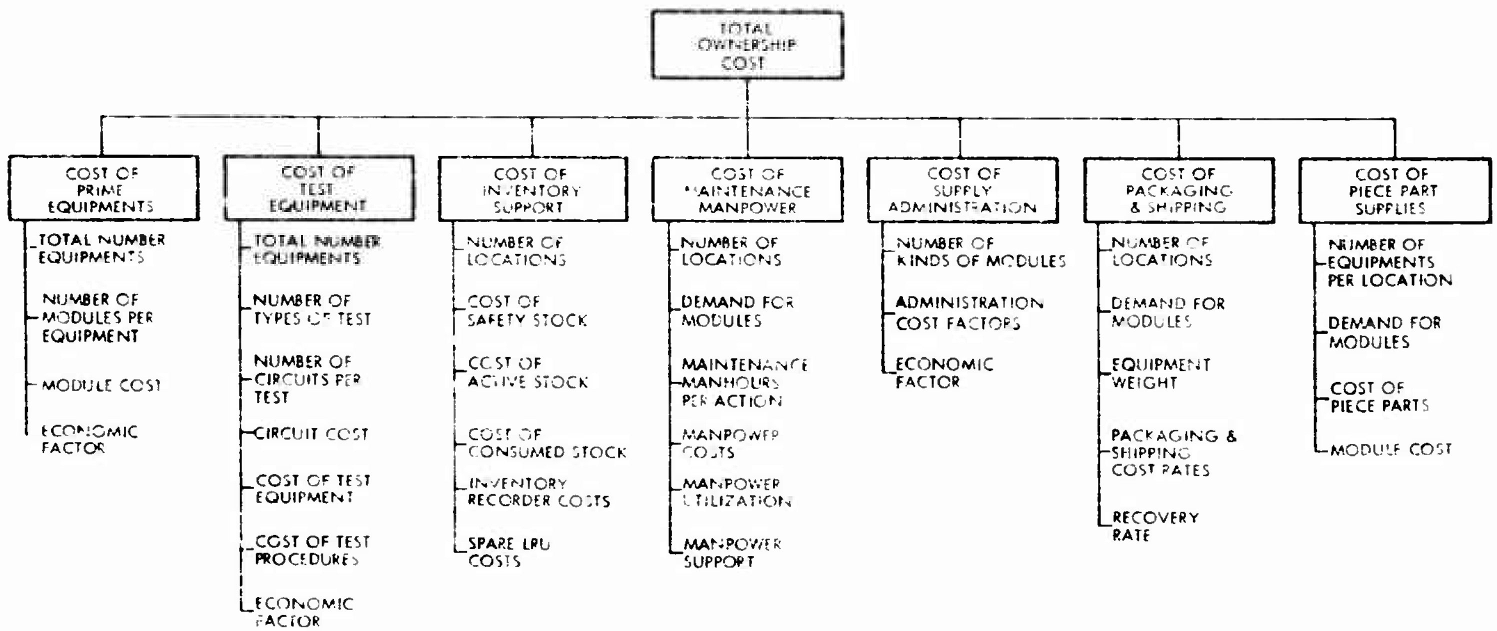



Figure 6-2. Major Factors Contribution to the Cost of Ownership

| $ COST TO BUY IT | $ COST TO APPLY IT | $ COST TO USE IT |
|---|---|---|
| HARDWARE | HARDWARE | |
| TEST SYSTEM(S) | INTERFACE DEVICES | SPARE PARTS |
| PERIPHERALS | ADAPTERS | SOFTWARE MAINTENANCE |
| | MODIFICATIONS | |
| POWER | | OPERATOR/MAINTENANCE PERSONNEL |
| FACILITIES (SCREEN ROOM, A/C, ETC.) | | CALIBRATION |
| | | FACILITY OVERHEAD |
| SOFTWARE | SOFTWARE | |
| COMPILERS | UUT PROGRAMS (DESIGN & VALIDATION) | |
| EXECUTIVES | | |
| ROUTINES | TEST GENERATORS | |
| SIMULATORS | SELF TEST FOR ADAPTERS/ INTERFACE DEVICES | |
| PROGRAM MANUALS | UPDATED PROGRAM MANUALS | |
| OPERATOR/MAINTENANCE MANUALS | OPERATOR/MAINTENANCE TRAINING | |
| SELF TEST PROGRAMS | | |

Figure 6-3. Resources Required - Dollars

**UUT Modification:** UUT modification should be examined with care. A simple UUT modification to provide compatibility with ATE can be accompanied by a major documentation and spares provisioning change. This is particularly significant where only a portion of the UUTs will be so modified, leading to a possible nomenclature change and re-qualification.

**Software:** Costs are incurred in preparation of UUT test software, ATE self-test software, software preparation aids such as compilers and assemblies, and in maintenance of software as UUTs change.

ATE Support: The ATE will need support funding for spares, special test or calibration equipment, and operational and maintenance documentation.

Manpower: Training, salaries, and berthing costs of the operational and maintenance crews are a factor.

Physical: Costs for real estate or ship space, power, and other physical plant facilities should be identified.

### 6.1.3 Quantification of Evaluation Factors

In order to minimize the subjectivity that is inevitably part of any equipment trade-off, attempts should be made to assign numerical values to evaluation factors. Certain factors are normally expressed in numbers, and they should be used as such with weighting constants used to match particular applications. Factors which are normally expressed numerically are:

- Costs
- Testing rate, UUT and self
- Availability
- MTBF
- MTTR
- Maintenance man hours per operating hour
- Operating man hours per operating hour
- Space
- Weight
- Power
- Environmental specifications

Figure 6-4 evaluates in steps the acceptable level of risk on a basis of operational need date vs. ATE design and production values. At one extreme, a six-month operational need date calls for selection of an ATE which is already operational and with free time to handle the proposed application. At the other end of the scale, only an operational need date more than two years away can accommodate a new ATE design as an acceptable risk.

Other factors do not lend themselves well to quantification with any degree of mathematical rigor. A case in point is "growth potential and flexibility" one of the suggested performance evaluators. Suppose that the candidate ATE stimulus spectrum exceeds present requirements. How should the excess be evaluated?

Dividing the candidate by the required spectrum gives a factor of two, for the case of 10 Hz - 200 kHz divided by 2 Hz - 100 kHz. Would a ratio of octaves be more significant? Then, too, is the 2 Hz limit more or less valuable than the extension from 100 to 200 kHz for the foreseeable future of the particular

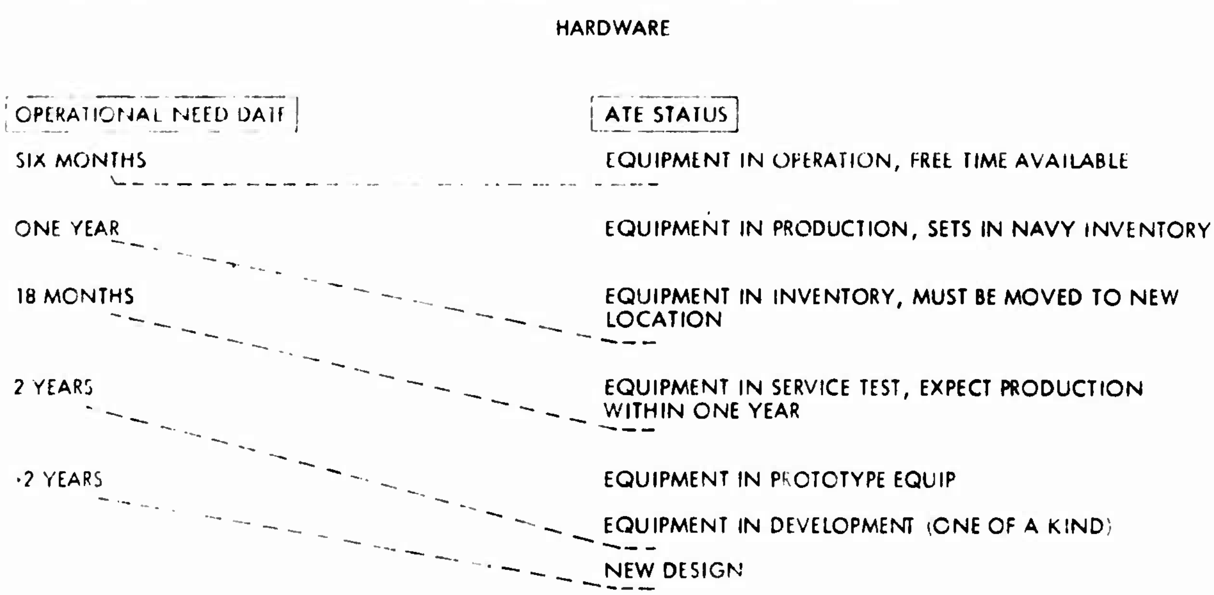



Figure 6-4. Risk

prime equipment under consideration? A temptingly easy way out is to use a binary approach, with yes or no for the existence or absence of a factor, but obviously this leads to being able to beat the system by providing trivial advantages which will score high but possibly be of little benefit. Regardless of the obvious difficulties, an attempt should be made to attach numerical values to all evaluation factors, using whatever criteria seem suitable. The values and their weighting coefficients may be subjective and very much application-dependent, but the approach will be more useful than one which has no numerical base. Fortunately, cost, which is the most significant evaluation factor, is numerical in nature. The evaluator's only problem with costs is their credibility, and this can be handled by dividing estimated costs by their confidence factor to give a factored cost.

## 6.2 CHECK LIST

This is a list of items which should be considered in the course of the ATE selection and evaluation procedure. The list includes procedural steps, evaluation factors and prerequisite information.

Obtain prime equipment descriptive material
Obtain support concept description
Develop test requirements listing

- Stimulus
- Measurement
- Switching
- On-line/off-line limitations

Examine prime equipment UUTs

- Accessibility
- Test interface

Identify external interface, if required

Identify costs

- ATE hardware
- ATE self-test software
- Software aids, compilers
- UUT test software
- UUT external interface devices, adapters
- ATE operator manning and training
- ATE maintenance manning and training
- ATE spares
- ATE facilities
- Software maintenance
- UUT modifications, including support impact
- Documentation

Analyze evaluation factors

- Test spectrum
- Environmental specs
- Physical characteristics
- Design/availability status
- Risk
- Monitoring level
- Fault isolation level
- On-line/off-line capability
- Displays

- Test rate
- MTBF
- MTTR
- Self-test
- Calibration requirements
- Personnel skills
- Training
- Spares policy
- Documentation
- Growth potential/flexibility
- Commonality to existing equipment

## 6.3 TEST EQUIPMENT TYPES

### 6.3.1 Introduction

This section provides basic definitions of test equipment terms and a brief survey of test equipment types. The information is not intended for systems engineers assigned to ATE selection who will already be familiar with the field, but for the familiarization of others involved in the prime equipment acquisition process whose background may be in other disciplines.

### 6.3.2 Basic Terms

Terms defined and discussed in this section have been used to describe test equipment elements, configurations, and operational modes. Confusion sometimes results where the same terms are used to define operational modes and equipment configurations, and where one configuration can operate in more than one mode (e.g., on-line, off-line). It will also be apparent from the listing

below that there is considerable overlap in terms. No attempt is made here to provide an extensive glossary. MIL-STD-1309, Definition of Terms for Automatic Test and Checkout, performs that function. The definitions below are limited to the major terms used in this report, plus some encountered in test equipment literature that are not significant enough or were created too late to have been included in MIL-STD-1309, but which could confuse anyone unfamiliar with their intent. Terms are arranged alphabetically.

Automatic: Automatic Test Equipment (ATE) or automatic test systems (ATS) are those which automatically perform test sequences and logical operations to determine operational status or corrective maintenance action required. Automatically controlled through a computer or a tape sequencer are stimulus generator selection and setting, measurement device selection and ranging, connection sequencing to the unit under test (UUT), and display or recording of the conclusions derived from the test logic. The attainable degree of automaticity is limited by the test accessibility of the UUT. Particularly at depot levels, it is often necessary for the ATE operator to disassemble the UUT to enable manual connection to test points during the otherwise automatic sequence. An ATE can be designed for optional manual operation where maintenance policy and level of operator training permit manual operation. Automatic test systems can be configured using building blocks which are conventionally designed as Conventional, Manual, or Standard (which see). So-called third generation ATE systems, now growing in prominence, depart somewhat from the direct association of test functions with building blocks, in that the computer, formerly used only as a control and calculating device, now also performs some of the stimulus and measurement functions.

Built-In: Built in test (BIT) or built-in test equipment (BITE) are test devices which are an integral part of the equipment being tested. BIT may be automatic,

manual, on-line, off-line, or a combination thereof. Although BIT and BITE are often used interchangeably, BIT may more correctly be considered to be the function performed by BITE. Also see Dedicated.

Centralized: A centralized test system is one which processes, at a central location, information gathered by test point data sensors at more than one remotely located equipment or system under test. (See Federated and Dedicated.) Centralized test systems are usually automatic, although a manual system could be envisaged which is also centralized. An extensive installation is implied, such as one which would test a ship's communication system, or other major equipment grouping.

Conventional: Conventional describes general purpose or standard (which see) laboratory type test equipment, such as signal generators and digital voltmeters.

Dedicated: A dedicated test equipment (or system) is one which is always connected to a particular test specimen. The definition differs from built-in, in that, while a dedicated test set may be co-located and even housed with equipment it is to test, it could conceivably be removed intact for use elsewhere. When a dedicated test system is used for more than one UUT, it becomes Centralized or Federated. This is clearly a confusing term, made worse by the occasional usage of BITE for Dedicated. Fortunately, Dedicated is more often used to categorize ATE computers, rather than entire ATE systems.

Fault Detection: This is the process of detecting the existence of a fault without actually locating it. It is thus similar to Readiness Testing and Performance Monitoring, which see.

which is manually operated. The operator of manual test equipment sets all stimulus and measurement devices and connects them to test points in the unit being tested. He also reads individual test results, evaluates performance, and diagnoses faults.

Measurement: The meaning is obvious. Voltmeters, ammeters, frequency counters, pressure gauges, and thermometers are examples of measurement devices.

Monitoring/Performance Monitoring: Monitoring usually signifies merely reading test parameters at intervals (or continuously) without the further application of test logic for interpretation of those readings. Two diverse examples, monitoring Exhaust Gas Temperature of a gas turbine engine, or reading cathode current of a linear amplifier do not in themselves necessarily indicate performance or condition. Adding an interpretation function through test logic converts Monitoring into Performance Monitoring, which is simply another name for testing. The distinction between monitoring and testing seems especially artificial when it is considered that monitoring of transmitter power output, for example, is a means of testing the performance of that unit with no further logic required except to verify that the transmitter is turned on.

Performance Monitoring is best defined as describing a test system operational mode in which tests are limited to those necessary to determine whether specified overall performance is being attained. Similarly to Fault Detection, the causes for malfunction are not necessarily identified. Performance Monitoring also bears similarities to Readiness testing (which see). Although Performance Monitoring is usually On-Line, the term does not exclude Off-Line application. Performance Monitoring can be applied to a test equipment category as well as an operational mode.

Fault Isolation (Level): Fault Isolation is the operating mode in which the automatic test system identifies the source of a malfunction within the equipment or system which it is testing. The level to which fault isolation is achieved refers to the equipment generation breakdown level, in descending order: group of modules (or assemblies); module; component. The two upper levels are also called Weapon Replaceable Assembly (WRA) and Shop Replaceable Assembly (SRA).

Fault Location (Level): Same as Fault Isolation (Level).

Federated: A little used term, Federated is a variation of the centralized system, and implies a similarly extensive installation. The idealized centralized system operates exclusively from raw data obtained from test point sensors in each equipment to be tested, and does all processing centrally. The federated concept is similar, except that it denotes acceptance of pre-processed results data from BITE or dedicated test equipment associated with the equipment to be tested.

Integrated: This is a term recently adopted by the Navy to describe an automatic test system (IATS) which is connected to a major system or a number of ship systems and equipments. Integrated implies less rigidity regarding central data processing than was assigned to Centralized, and is thus closer to Federated in meaning, but clearer. It is not yet certain whether Integrated will grow into a generic term, or whether it will be associated only with the first system of its type, originally conceived for the Trident program.

Manual: Manual, is often used, as synonymous with Conventional or Standard (which see) laboratory test equipment, and is opposite to Automatic. However, it can also refer to General or Special Purpose (which see) test equipment

Off-Line/On-Line: These terms often cause confusion because they are used to describe test equipment configurations as well as test equipment operating modes, and the two categories are, more often than not, inconsistent. MIL-STD-1309 is clear in its definition of off-line and on-line testing. Off-line testing consists of tests performed while the tested equipment is not performing its normal operational function. A radio receiver which is temporarily disconnected from its antenna to receive a test stimulus is considered as being tested off-line, even if the test is being performed at the operational site. Any operational interruption during a test qualifies that test as off-line. The most obvious example of off-line testing is the removal of an equipment from its installation site for test at another location. An on-line test is one which is performed while the equipment is in normal operation, and which in no way degrades or interferes with the normal operational use of the supported equipment. A simple example would be a voltage measurement and evaluation device which indicated when a power supply was operating out of tolerance, but which did not affect the performance of the supply in its operational environment and usage.

Off-line test equipment is equipment which is not permanently connected to the supported equipment. A depot test set is off-line. Shop test equipment is off-line if it is only connected to the supported equipment during corrective or periodic maintenance. On-line test equipment is always connected to the supported equipment. BITE is on-line. Also, any external test equipment, whether centralized, dedicated, or any other type, becomes on-line if it is always connected to the prime equipment.

It is clear that both off-line and on-line testing can be performed by either off-line or on-line test equipment, and to avoid confusion, the terms on-line and off-line must be qualified as to whether they refer to test mode or to test equipment.

Purpose, General/Multi-/Special: Terms which describe Purpose are imprecise and overlap enough to generate considerable confusion. They should be used sparingly.

General Purpose: General Purpose test equipment can be automatic or manual although it usually relates to the latter. General Purpose usually means that capabilities and operational flexibility exist beyond those immediately needed, thereby enabling a wide range of UUT types to be tested. For example, a frequency synthesizer may be automatically programmable (or manually settable) from 1-50 MHz, even though only a portion of that range may be needed by the group of UUTs for which the synthesizer was originally designed. General Purpose can appear to imply universal applicability, which is not necessarily so.

Multi-Purpose: Multi-Purpose, as the name implies, merely signifies that the test equipment can be used for more than one UUT. Although the term is not much used, it is more precise than General Purpose, and interchangeable with it, depending on the subjective evaluation of when the number of purposes approaches general as a limit.

Special Purpose: Special Purpose is most accurately defined in a negative sense. It denotes test equipment designed for a particular purpose and probably inadequate for any other purpose. Special purpose test equipment will employ spot

frequency generators instead of wide range signal generators, and switching and logic (perhaps wired-in) will be tailored exclusively for the one application.

Readiness Testing, Operational/System: Except for fine shadings of meaning, Operational and System Readiness testing are identical to Performance Monitoring. Usage to date implies that Readiness testing is done an a larger scale than Performance Monitoring. For example, the AEGIS Operational Readiness Test System (ORTS) determines readiness of an entire weapon system, including data processors, radars, and missile systems. The distinction between Operational and System Readiness becomes cloudy, except where operational readiness is defined as requiring readiness of more than one system. In the other direction, if performance of an HF transmitter is monitored as satisfactory, the radio man would consider that unit to be operationally ready.

Standard: Standard test equipment describes normal laboratory test equipment, usually already in inventory, or of a similar type.

Stimulus: MIL-STD-1309 succinctly states it: "Stimulus is any physical or electrical force applied to a device intended to produce a measurable response." Audio and radio frequency signal generators are stimulus devices. Power supplies to power the unit being tested are classifed as stimulus. Even though passive, a dummy load is also considered to be stimulus.

Switching: The connection or re-connection of stimulus and measurement devices are referred to as switching in automatic testing, where the implementation can be a significant part of the system. The term is not used as much in normal testing, where switching is an inherent part of using stimulus and measurement equipment.

Unit Under Test (UUT): The most important, despite its alphabetical ranking, is the unit under test. MIL-STD-1309: "Any system, set, subsystem, assembly, subassembly, and so forth, undergoing testing." Past literature may contain references to AUT or SUT, for assembly or system under test, respectively. The MIL-STD-1309 definition is comprehensive enough to make the others unnecessary.

## 6.4 DATA BANK Hughes Aircraft Corporation

Although shown as a part of Section 6 for the sake of completeness, the Data Bank results are so extensive that a separate document will probably result.

# Procedure for the Selection of Automatic Test Equipment (ATE)

**August 1974**

**ATEMAT (MAT 03T)**

**HEADQUARTERS, NAVAL MATERIAL COMMAND**

# PROCEDURE FOR THE SELECTION

# OF

# AUTOMATIC TEST EQUIPMENT (ATE)

**AUGUST 1974**

**ATEMAT (MAT 03T)**

**Headquarters, Naval Material Command**

A i

## EXECUTIVE SUMMARY

### SITUATION

As a function of its responsibility in the ATE (Automatic Test Equipment) area the ATE Management and Technology Office (ATEMAT MAT 03T) conducted a review of ATE selection and acquisition procedures within the Naval Material Command and surfaced a major problem in the time phasing of ATE selection and acquisition events. To alleviate the problem ATEMAT sponsored the development of a selection procedure emphasizing proper timing. Follow-on efforts will address the acquisition procedures as a natural augmentation to this procedure.

### METHODOLOGY

Investigation by the Test Equipment Technology Support Office (TETSO) of the support activity (including Integrated Logistics Support and its components) having a direct impact on the ATE selection process revealed that essential actions were often not accomplished during the proper time in a development phase and in some cases in later phases. A joint task group comprised of ATE, logistics support, and modeling specialists was assembled at NELC to review previous study results in ATE selection and to identify the areas that needed improvement. Review of current ATE selection practices, related support activities, and pertinent documentation was conducted by the joint task group. Tools, aids and the phasing guidelines for ATE selection events were developed and incorporated in this report.

### CONCLUSIONS

The most important conclusions drawn from this study (and documented in this report) are:

a. Selection of ATE is an integral part of prime system/platform design.

b. The Advanced Development/Validation phase is the most critical phase in the ATE selection process.

c. Selection of ATE is an integral part of the ILS/LSA process.

### RECOMMENDATIONS

This selection procedure should be incorporated into an ATE selection and acquisition guide, and other documents pertaining to the selection process should be modified to reflect adherence to these recommended procedures. Until the selection and acquisition guide is available, this document should be used as an interim guide to the selection of ATE.

## TABLE OF CONTENTS

## 1.0 INTRODUCTION

### 1.1 Background

The selection of the proper automatic test equipment (ATE) to satisfy a platform or prime system need, has proved to be a complex task which is often underestimated. Various concepts and hardware must be proposed, and each compared with one another in relation to their performance, availability, utilization and the affect on the operational readiness of that platform or system. In the past, mistakes have been made which have caused delays in deployment, excessive costs, poor reliability and inadequate performance. This report describes procedures to be employed in the selection of the proper ATE for a given job. The framework is built around the acquisition process as described in SECNAVINST 5000.1 and the Integrated Logistic Support (ILS) procedures identified in NAVMATINST 4000.20.

### 1.2 Applicable Documents

These documents apply generally to the subject of the procedure. For references which contain more details, consult the documents listed in Section 7.

a. NAVMATINST 3960.4A of 26 December 1973; this instruction provides policy and responsibility for automatic test, monitoring and diagnostic systems and equipment.

b. NAVMATINST 4000.20A of 18 March 1971; integrated logistic support planning policy.

c. MIL-STD-1388 of 15 October 1973; this military standard describes the logistic support analysis procedure.

d. SECNAVINST 5000.1; all Navy system acquisitions are covered by this instruction.

e. OPNAVINST 5000.42 of 1 Jun 1974; Weapons systems selection and planning is revised by this instruction.

### 1.3 Purpose

The procedures set forth herein are to be used by Program Managers, Acquisition Managers and others associated with the acquisition of Navy hardware. Since each program is unique, this procedure has been structured for selective use, allowing the user to select guidance responsive to the needs of his program. The procedure is divided into five sections which parallel the phases of the acquisition process set forth in SECNAVINST 5000.1. Each section provides the guidance needed during that phase of a hardware (i.e. platform, system, equipment) acquisition that will insure concurrent development and acquisition of associated ATE.

Selection of ATE is a support function that is a part of the Integrated Logistic Support/Logistic Support Analysis (ILS/LSA) areas of platform and prime system development. All of the actions taking place in parallel to the ATE selection are included for each phase of the acquisition cycle. This enables the planners/managers to key the ATE selection actions to events in the acquisition process. Too often ILS actions in general, and ATE selection in particular,

takes place later than what would be optimum. Only by the parallel development of ATE and the prime equipment, can it be assumed that the equipment will be fully effective when introduced for fleet use.

## 1.4 Approach

Each section of this procedure sets forth an objective to be achieved, in so far as ATE is concerned, during a single phase of equipment acquisition. Step-by-step procedures are provided for achieving this objective, assuring consideration is given to each aspect of the problem and that these actions are taken in the proper sequence. To further assist in the acquisition process, existing aids to assist in this process are identified, along with their recommended use.

Input requirements for each phase are identified, and to the extent possible, the sources of these inputs are named. Outputs or products that result from the satisfactory accomplishment of a phase are also defined to further assist in identifying the tasks to be accomplished during each phase of the acquisition.

## 1.5 Organization of Report

This report is composed of four general areas which consist of Section 1, Sections 2 through 6, Section 7 and Section 8. These cover the following areas:

Section 1 - Provides introduction and a management overview.

Section 2 - 6 - Contains a detailed description of the major efforts performed during each prime hardware development phase. Each phase is covered in a separate section.

Section 7 - Is a list of the tools and aids that are available to the Program Manager and his supporting ILS managers, to assist him in the ATE Selection Process.

Section 8 - Provides conclusions and recommendations for follow-on efforts.

## 1.6 Overview of ATE Selection Procedure

During the Conceptual Phase, the prime hardware is defined basically by needs and objectives. General support requirements are specified, such as operational availability. From these, an ATE concept can be defined in terms of broad performance monitoring needs and the degree of off-line testing needed at each maintenance level.

Advanced Development Phase activities involve definition of the support system in relation to the hardware design. On-line ATE (BIT/BITE) hardware must be designed in parallel with prime equipment design. This phase ends with the contract to proceed with the detail design and the Full Scale Development Phase.

In addition to the prime hardware design and development, the support equipment (including ATE) is also developed during the Full Scale Development Phase. Prototype ATE is evaluated and assessed. Redesign/modification is also performed.

During the Production/Construction Phase, off-line ATE specifications are completed, and procurement initiated and completed. Software and Test Program Sets (TPS) are developed for support/test of the prime hardware. Changes and modifications to the ATE hardware/software may result from the TPS production. Evaluation and assessment of the ATE should also take place during this operation. Information gained from the evaluation/assessment, if of sufficient magnitude, can serve as a foundation for a major Engineering Change Proposal (ECP) to clean up any deficiencies in the ATE.

### 1.6.1 Selection Process

Figure 1-1, ATE Selection/Prime Hardware Acquisition Process, provides a flow chart description of this overview. This figure forms the basis of subsequent sections. However, it should be recognized that (1) the process is iterative in nature and (2) the ATE selection process must be tailored to specific prime hardware peculiarities.

### 1.6.2 Phase Flow Overview

There are four major prime hardware development phases which are covered in Figure 1-1 for a brief overview of the ATE selection process.

Figure 1-1 is a matrix of these four major development phases against the following:

a. Objectives
b. Principal Efforts
c. Logistic Support Factors
d. Logistic Support Design Process
e. ATE Selection Process
f. Output Documentation

Each of the following five sections is organized using (a) through (f) categories as headings. Categories (a) and (b) are overall prime hardware system design functions. Categories (c) and (d) are ILS functions. Category (e) is the ATE selection process and category (f) summarizes the output documentation relative to the entire process.

# PROGRAM INIT

NEED IS VALIDATED
PERFORMANCE PARAMETE
PLAN FOR ALTERNATE EV
ACQUISITION STRATEGY
RISK IS LOW AND IDENTIFI

## (CONCEPTUAL)

DSAR

FUNCTIONAL

**OBJECTIVES**

- To examine technical, military and economic bases for major development programs and alternate systems
- To select a preferred system concept
- To determine whether the preferred system is sufficiently attractive to warrant movement to Advanced Development activities.

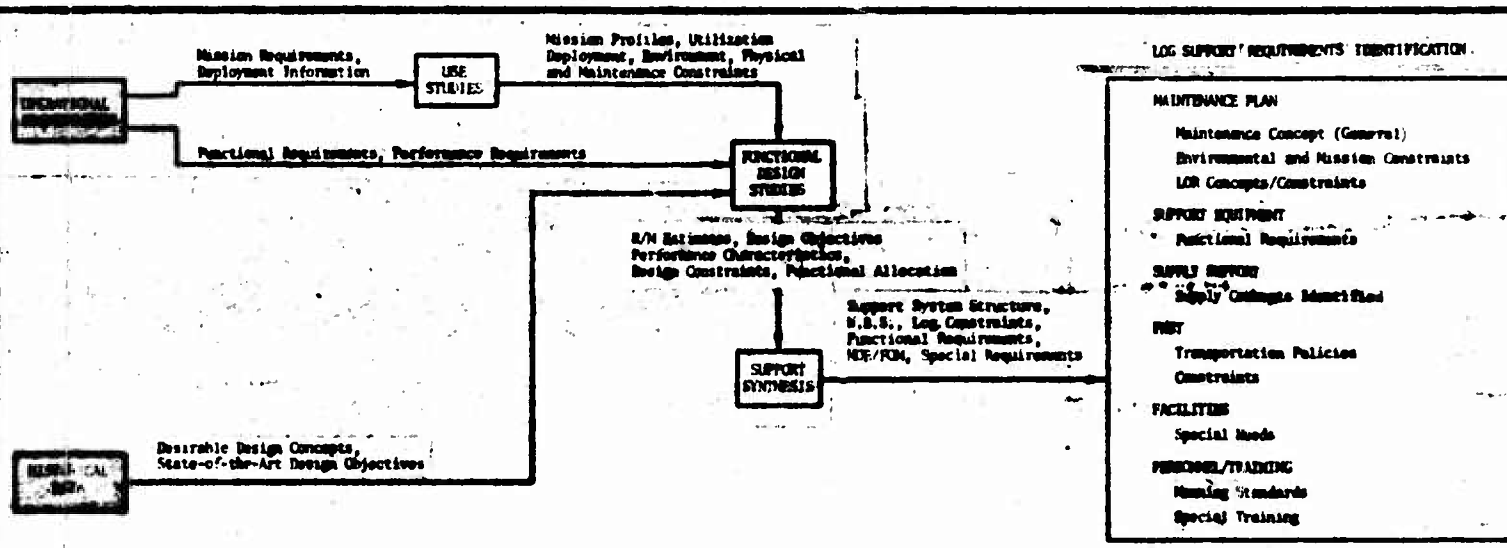
**PRINCIPAL EFFORTS**

- Identification and definition of conceptual systems
- Analyses (i.e., threat, mission, feasibility, risk, cost, tradeoffs, logistic support, and worth)
- Design, experimentation and test of operational requirement assumptions and marginal technology
- Highly iterative activities working toward the generation of evidence to meet the entry considerations of Validation activities

**LOGISTIC SUPPORT FACTORS**

- Initial planning of a generic variety
- ILS functions to provide recommended support parameters for appropriate logistic elements
- Meeting the need for a broad, general integrated logistic support plan, and noting any special problems that have been observed through the logistic effort

**LOGISTIC SUPPORT DESIGN PROCESS**




**ATE SELECTION PROCESS**

DEFINE ATE CONCEPT

1. Performance Monitoring Needs i.e. (On-Line, BIT, BITE, Self-test)
   a. System and Platform monitoring levels
   b. Environment (i.e. Safety, Damage Control, EMCON)
   c. Configuration (i.e. Communication Channels)
2. Degree of Off-Line Automatic Testing at Organization, Intermediate, and Depot (O,I,D) levels.

**OUTPUT DOCUMENTATION**

PTA

START LSAR— — —CONTINUOUS THRU PRODUCTION

DP
PMP
APP
DCP

# AM INITIATION PHASE

- NEED IS VALIDATED
- PERFORMANCE PARAMETERS MATCH NEED
- PLAN FOR ALTERNATE EVALUATION IS FEASIBLE
- ACQUISITION STRATEGY
- RISK IS LOW AND IDENTIFIED

## (VALIDATION OR ADVANCED DEVELOPMENT)

DSARC I

FUNCTIONAL DESIGN

- To establish firm and realistic performance specifications, including technical interfaces
- Define Acquisition organization and responsibilities
- Demonstrate that high risk areas can be eliminated or reduced to a reasonable level
- Verify technical approac
- Establish firm and reali estimates and schedules deployment phases

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- Hardware (prototype) development and evaluation for definition of major program characteristics and higher level of confidence in risk resolution
- Refinement of emerging performance specifications
- Refinement and validatio
- Completion of Prelimina

- Continuing examination and evaluation of support parameters
- Examination of special problems of logistic needs

S IDENTIFICATION

(General)
ssion Constraints
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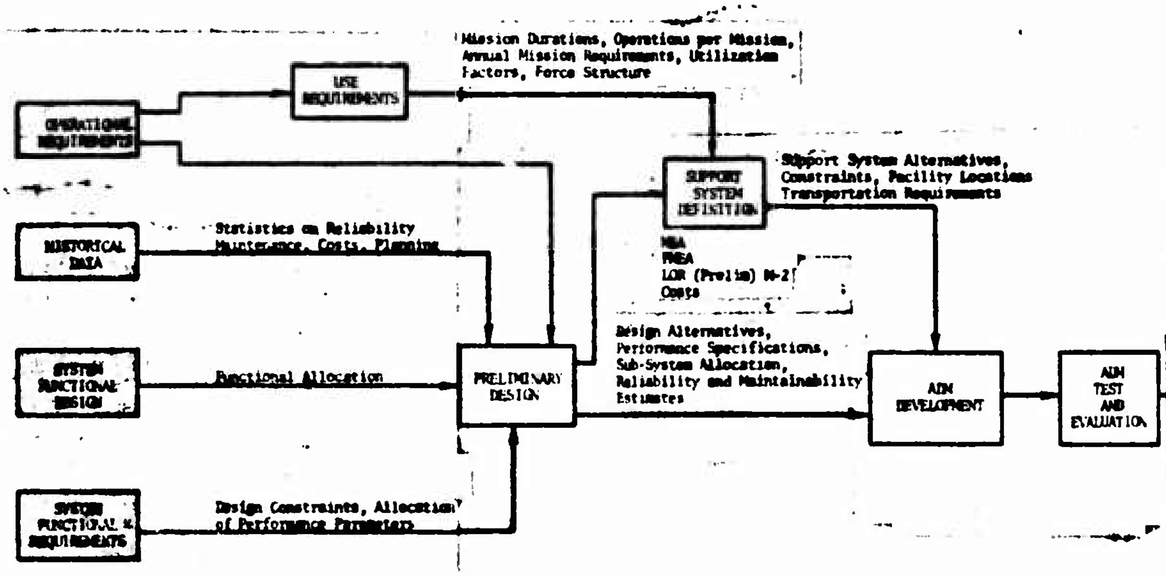



LOG SUPPORT REQ

MAINTENANCE PLAN
- Maintenance Concept (R)
- Maintainability Allocat
- Reliability Allocation

SUPPORT EQUIPMENT
- Functional Requirements
- Preliminary LOR Decisio
- Testing Constraints
- GFE/CFE Data

PHST
- Transportation Modes
- Packaging Constraints
- Regulations

FORMULATE ATE ALTERNATIVES

1. On-Line ATE i.e. (BIT/BITE)
   a. Search Data Bank(s)/do literature search to determine alternative testing concepts and techniques
   b. Analyze approaches used in similar systems and platforms
   c. Select "best approach" considering life cycle costs, the effect on platform and system's operational readiness, technical risk and schedule
   d. "Design-in" ATE/BIT hardware

2. Off-Line ATE
   a. Search Data Bank to match UUT requirements with available ATE
   b. Identify Alternatives:
      (1) Existing ATE (or building blocks)
      (2) Modification of existing ATE
      (3) Development of new ATE

c. Evaluate Alternatives in Relati
   (1) Life Cycle Costs
   (2) Effect on Platform or syst
   (3) ATE performance (i.e. prob speed, operator usability)
   (4) ATE reliability, availabil
   (5) Utilization factors (i.e. location of ATE)
   (6) Technical risk
   (7) Schedule

PTA

ATION

DP
PMP
APP
DCP

FIGURE 1-1. ATE SELECTION/PRIME HARDWARE ACQUISITION PROCESS

# FULL SCALE DEVELOPMENT

NEED AND THREAT REAFFIRMED
SYSTEM ALTERNATIVES CONSIDERED
SPECIAL LOG NEEDS IDENTIFIED
DEVELOPMENT COSTS
LIFE CYCLE COSTS
TECHNICAL RISKS IDENTIFIED
FSD PLAN REALISTIC

NEED AND
COST OF
ENGINEER
PRODUCTI
TECHNICA
OPERATIO
REALISTIC

approaches

d realistic life cycle cost
edules for production and

DSARC II

PRELIMINARY DESIGN

- To output a hardware model and its required documentation as a precondition to produce the system or equipment for inventory use

lidation of conceptual studies

liminary Engineering Design

- Continuing assessment of risk to uncover technical and engineering problems requiring solution
- Development milestones established to demonstrate achievement of objectives

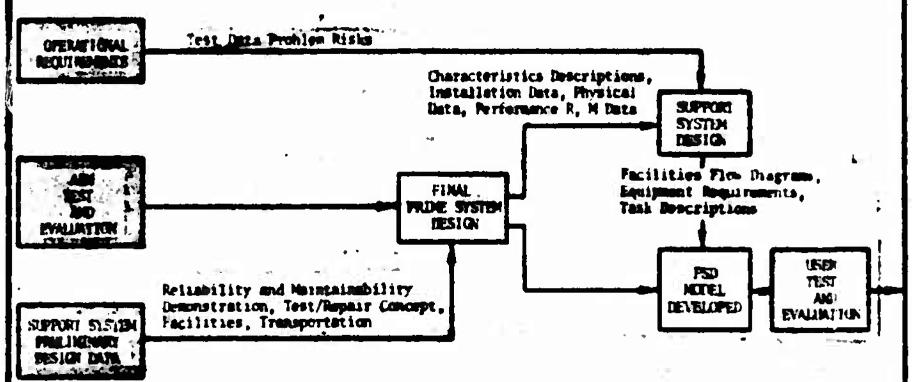
- Providing of assurance that problems encountered during Validation activities have in fact been solved or reduced to a reasonable risk level
- Validation and verification of data requirements basic to the emerging system design disclosure package

- Formalization and design of logist system early in the FSD Phase, inc appropriate performance milestone development, production and deplo
- Completion of detailed design of equipment

- Providing effort to assure the sufficiency and adequacy of the formalized logistic support program
- Early in FSD provide structured ILS Plan

PORT REQUIREMENTS IDENTIFICATION

| | |
|---|---|
| ncept (R) | TECHNICAL DATA |
| Allocation | Item Identification (FSD) (PID's) |
| location | FACILITIES |
| | Special Needs (R) |
| | I/D Level Requirements |
| irements (R) | PERSONNEL/TRAINING |
| Decisions | Manning Requirements |
| aints | Special Skill Requirements |
| | Training Capabilities |
| | Task Analysis Data |
| Modes | SUPPLY SUPPORT |
| raints | Supply Concepts (R) |
| | Special Requirements |




LOG SUPPORT REQUIREMENTS IDENTIFICA

| | |
|---|---|
| MAINTENANCE PLAN | TECHNICAL DATA |
| Detailed Maintenance Plan | Item Identifi |
| Optimum LOR | (PID's) |
| SUPPORT EQUIPMENT | FACILITIES |
| Equipment Requirements | Requirements |
| Equipment Cost Estimate | Costs |
| Test Levels and Concepts | Functional Sp |
| Procurement Concept | Location |
| SUPPLY SUPPORT | PHST |
| Item Identification | Physical Data |
| Quantity Required | Dimension Dat |
| Parts List | Transportatio |
| Production Lead Time | Packaging Req |

PERSONNEL/TRAINING
Skill Levels
Manning Metrics
Special Training
Training Capabilities
Human Factors Considerations

in Relation to:

s or system's operational readiness
i.e. probability of failure detection,
ability)
vailability and logistic support
s (i.e. utilization rate, growth potential,

1. On-Line ATE i.e. (BIT/BITE)
   a. Reevaluate, design, and refine the BIT/BITE
   b. Develop/build BIT/BITE into Prime System or Platform
   c. Perform ATE Technical Evaluation/Operational Evaluation as part of the Prime System or Platform Evaluation
   d. Assess ATE Selection

2. Off-Line ATE
   a. Reevaluate requirement and develop/procure an ATE model(s) Hardware/Software
   b. Evaluate supporting test program development aids (computer generated/assist)
   c. Perform ATE Technical Evaluation/Operational Evaluation
   d. Assess ATE Selection

PRELIMINARY ILS PLAN

FSD SPECIFICATION

PMP
DCP
APP

FINAL ILS PL

PRODUCTION
SPECIFICATI

LE DEVELOPMENT



PRODUCTION

NEED AND THREAT REAFFIRMED
COST OF OWNERSHIP QUALIFIED
ENGINEERING DESIGN PRACTICAL
PRODUCTION AND LOGISTICS PROBLEMS CONSIDERED
TECHNICAL RISK RESOLVED
OPERATIONAL SUITABILITY VIA T AND E
REALISTIC PLAN FOR PRODUCTION

- To output a hardware model and its required documentation as a pre-condition to produce the system or equipment for inventory use

DSARC III

DETAILED DESIGN

- To produce or construct a system having met all the requirements, from the Program Initiation Phase through the Full-Scale Development Phase, in (1) assessment of risk, (2) system and hardware proofing, and (3) appropriate tradeoffs
- To achieve the ultimate goal of system or equipment availability (viz, item is reliable, maintainable, and supportable to perform its mission throughout the remainder of its programmed life cycle)

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- Providing of assurance that problems encountered during Validation activities have in fact been solved or reduced to a reasonable risk level
- Validation and verification of data requirements basic to the emerging system design disclosure package
- Formalization and design of logistic support system early in the FSD Phase, including appropriate performance milestones throughout development, production and deployment
- Completion of detailed design of prime equipment
- Production (or construction) of the system or equipment
- Recognition that some full-scale development and minor production activities may overlap (i.e., hard tooling requirements and long lead time items or components)

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- Providing effort to assure the sufficiency and adequacy of the formalized logistic support program
- Early in FSD provide structured ILS Plan
- Validated Logistic Support Analysis Record (LSAR)
- Careful monitoring to assure timely delivery of logistic support resources
- Validation of prime/equipment compatibility with test equipment and support system
- Adequately updated ILS Plan
- Review and assessment of activities and deliverables to achieve logistic support program goals

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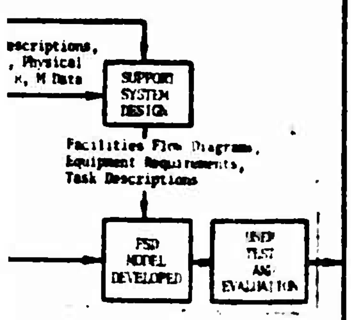



LOG SUPPORT REQUIREMENTS IDENTIFICATION

MAINTENANCE PLAN
- Detailed Maintenance Plan
- Optimum LOR

SUPPORT EQUIPMENT
- Equipment Requirements
- Equipment Cost Estimate
- Test Levels and Concepts
- Procurement Concept

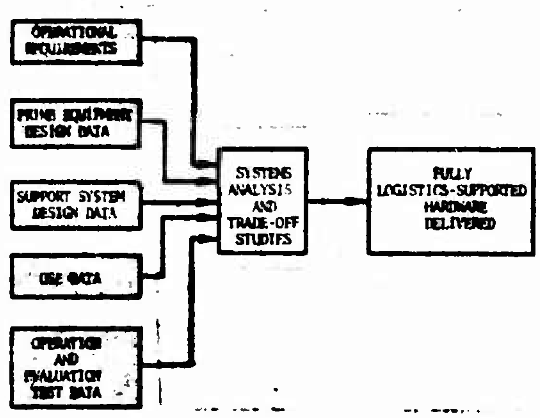
SUPPLY SUPPORT
- Item Identification
- Quantity Required
- Parts List
- Production Lead Time

TECHNICAL DATA
- Item Identification (Prod (PID's)

FACILITIES
- Requirements
- Costs
- Functional Specifications
- Location

PHST
- Physical Data
- Dimension Data
- Transportation Media
- Packaging Requirements

PERSONNEL/TRAINING
- Skill Levels
- Manning Numerics
- Special Training
- Training Capabilities
- Human Factors Considerations

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Platform Evaluation as ion

2. Off-Line ATE
   a. Reevaluate requirement and develop/procure an ATE model(s) Hardware/Software
   b. Evaluate supporting test program development aids (computer generated/assist)
   c. Perform ATE Technical Evaluation/Operational Evaluation
   d. Assess ATE Selection

1. On-Line i.e (BIT/BITE)
   a. Develop Pre-Production Model with BIT/BITE in conformance with results of Full Scale Development Model
   b. Perform system Acceptance Test (at factory)
   c. Assess ATE Selection
2. Off-Line ATE
   a. Procure ATE systems to meet Production Performance Specifications developed during the Full Scale Development Phase
   b. Run Acceptance Tests on the production model ATE (Test Program Sets should be developed concurrently to control ATE)
   c. Assess ATE Selection

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FINAL ILS PLAN

PRODUCTION SPECIFICATION

PMP
DCP
APP

CONTINUOUS FROM PROGRAM INITIATION

COMPLETE LSAR

1.7 Personnel Engaged in the Selection Process

Selection of the proper ATE is normally a team effort. Three types of personnel are usually required on the selection team.

a. A representative from the prime hardware design team, especially when BIT/BITE is used.

b. A representative from the ILS manager's office.

c. An expert on the design and application of ATE.

The first two categories are normally a part of the prime hardware development team. Expertise on ATE selection can be obtained from a variety of sources. The most appropriate starting points are the SYSCOM ATE focal points (AIR 5342, ELEX 4804 or SEA 98) or ATEMAT (MAT 03T) and the Test Equipment Technical Support Office (NELC 4050).

## 2.0 CONCEPTUAL PHASE

### 2.1 Objectives

During the conceptual phase of development, the prime objectives are to:

a. Reveal whether or not there are similar or duplicate developments underway which meet the operational requirements. Information resulting from this analysis could either provide a system concept for further development, or eliminate the proposed development because of parallel development of another system that satisfies the requirements;

b. Select a preferred system concept; and

c. Determine whether the preferred system is sufficiently attractive to warrant movement to the advanced development phase.

Note that these obectives relate to the total conceptual phase activity of which the ATE selection process is a subset.

### 2.2 Principal Efforts

Principal efforts during the conceptual phase are:

a. Identification and definition of conceptual systems.

b. Analyses (i.e., cost, threat, mission, feasibility, risk, trade-offs, logistic support, and worth) of the alternatives.

c. Design, experimentation and test of operational requirement assumptions and marginal technology. Most of the activity during the conceptual phase of the system development cycle is not hardware oriented, but some hardware related effort may be required. This involves testing items of hardware which represent advances in technology (or on the borderline of new technology). Other experimentation may involve simulating (with mock-ups) operational situations to establish their feasibility.

d. Highly iterative activities generating data supporting continuation of the program into the Validation or Advanced Development phase.

Part of the identification of conceptual systems (2.2a) involves the identification of "ATE concepts" in addition to the other prime system concepts. The same activities that apply to the prime system conceptualization procedure also apply to the ATE associated with it. These activities include analysis and trade-offs, contributing to the decision process for further development.

### 2.3 Logistic Support Factors

In the conceptual phase, the following planning and other activities should take place:

a. Initial ILS planning of a generic type.

b. Functional analysis to develop recommended support alternatives for appropriate logistic elements (the ten components of ILS).

c. Meeting the need for a broad, general integrated logistic support plan, and noting any special problems that have been observed through the logistic effort

2.4 Logistic Support Design Process

Most of the following material was developed around the Military Standard on Logistic Support Analysis (MIL-STD-1388) and is presented in a form that is suitable for ATE selection discussion. Refer to Figure 1-1, Conceptual Phase, Logistic Support Design Process to follow this discussion.

The two inputs to this process are the operational requirements and the historical data. These are indicated by the shaded boxes on the left hand side of Figure 1-1 (in Logistic Support Design Process). Operational Requirements have four components:

Mission Requirements
Deployment Requirements
Functional Requirements
Performance Requirements

The first two of these requirements lead to use studies which yield Mission Profiles, Utilization, Deployment, Environment, Physical, and Maintenance Constraints.

Historical data results in desirable design concepts and state-of-the-art design objectives.

Functional design studies are conducted on the output data from the Operational Requirements and historical data paths. These functional design studies involve describing each function as a "black box" with an input and output. Each functional box is placed in the design and the following factors are determined:

Reliability/Maintainability Estimates
Design Objectives
Performance Characteristics
Design Constraints
Functional Allocation (i.e., partitioning the functions among various building blocks)

It is during the functional design studies that various approaches to ATE, and BIT (Built-In Test) should be considered. Remember its never too early to start planning!

From the Functional Design Study output, the Support Synthesis Process can start. The results of the support synthesis process are:

Support System Structure

WBS (Work Breakdown Structure) for the support system

Logistic Constraints

Functional Requirements (identification and refinement of the initial functional requirements--this process continues throughout development)

MOE/FOM (Measure of Effectiveness/Figure of Merit) Development

Special Requirements (this is another point at which special purpose ATE or BIT/BITE can be considered)

It is after these operations that the Logistic Support Requirements Identification takes place. Logistic Support Requirements Identification starts during the Conceptual Phase and continues through the full scale development phase. One of the things which are accomplished during the identification of logistic support requirements is the functional definition of ATE/BIT. The major events in this identification process are:

a. Maintenance Plan - consisting of:
- Maintenance Concept (general)
- Environmental and Mission Constraints
- LOR (Level of Repair) Concepts/Constraints

b. Support Equipment:

Functional Requirements for all support equipment including General Purpose Electronic Test Equipment (GPETE), ATE and BIT

c. Supply Support:
- Supply Concepts are identified to support the prime system - the prime system supply concept will have a direct impact on ATE selection, for it may dictate where repair and test of a given item will take place.

d. PHST (Packaging, Handling, Storage and Transportation):
- Transportation Policies are established
- Constraints are identified and placed on PHST

e. Facilities:
- Special needs are identified

f. Personnel/Training:
- Manning Standards for the prime equipment and support system (ATE included) are identified
- Special Training requirements are surfaced - this includes ATE operation and support (software and programming is germane)

## 2.5 ATE Selection Process

### 2.5.1 General

Definition of the ATE concept is the main thrust of the Conceptual Phase of the ATE Selection Process. There are two main functions which must be performed in the ATE concept formulation phase. These are establishing performance monitoring need and determining the degree of off-line ATE at organizational

intermediate, and depot levels. As indicated in Figure 1-1, there are three subsets of the Performance Monitoring Needs that need to be considered.

a. To what level will system and platform performance monitoring be performed:

b. What environmental factors (i.e., safety, damage control, EMCON-Electomagnetic Emission Control) will be monitored?

c. What system configurations need to be displayed (i.e., communication channels, electrical power plant status)?

2.5.2 Selection Procedure

Procedures which are followed in the ATE selection process are linked to various steps of the Logistic Support Design Process. An orderly step by step general ATE selection process would follow the order presented in Figure 2-1, Preliminary Support Concept Definition. Each of the following paragraphs are keyed to the steps outlined in Figure 2-1.

2.5.2.1 Define Hardware

It is during the hardware definition cycle of the system to be supported, that the ATE concept is based. Preliminary hardware definition efforts correspond to the Functional Design and Support Synthesis activities in the Logistic Support Design Process. The factors which are considered in the hardware definition are performance requirements, a functional description of the total system (or platform) and its building blocks, reliability, maintainability, availability, budgetary factors (cost, space, weight, and power), and hardware/module breakdown. Since during the conceptual stage the direct association with hardware is limited to similar systems, or known components which will become a part of the prime hardware; little information is available on input/output parameters, operating tolerances, and detailed hardware layouts/wiring diagrams.

From the information available at this stage of development, it is possible to start formulating the performance monitoring needs of the system. Such things as BIT, BITE, On-Line Test, and Self Test needs can be formulated. These needs can then be blended into the definition of the prime system and the support system. This effort will produce a preliminary integrated prime hardware and support system design. Subsequent iterations with the other factors/operators in the definition process may change the hardware definition but certain general attributes remain constant. It is quite feasible to define BIT/BITE or On-Line Test during the first cut at a hardware definition (design) and have it remain relatively stable through the development cycle. Because of the highly integrated nature of BIT/BITE and the prime hardware it is almost mandatory that it be specified/defined during the conceptual phase of development. It is too late to wait until the full scale development or production phases to introduce BIT/BITE or On-Line ATE. Performance monitoring needs should also be identified

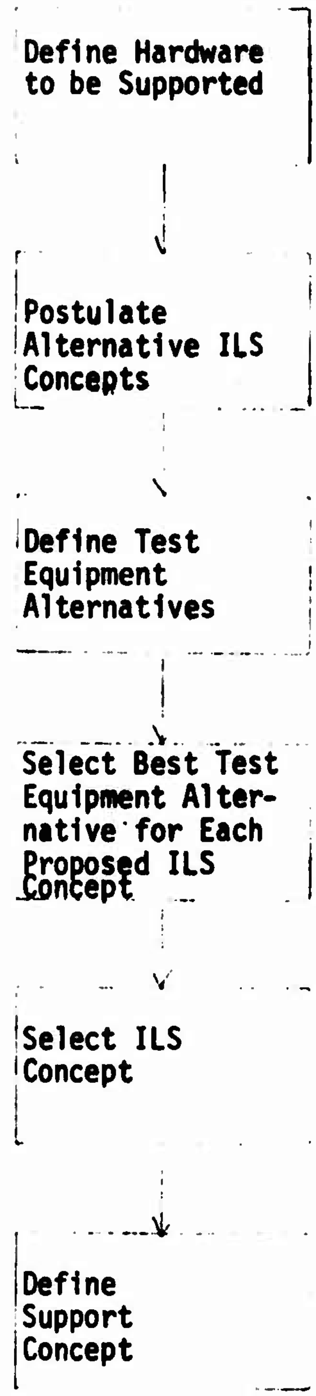


Figure 2-1 Preliminary Support Concept Definition

early in the development cycle so that the requisite sensors and monitoring points can be designed/built into the prime hardware. The decision to use full or partial off-line ATE can also be made this early in the development cycle, and they should be in order to allow an evolutionary selection process. (See 2.5.2.3)

2.5.2.2 Postulate Alternative ILS Concepts

Alternative ILS concept formulation is a process which involves Level of Repair (LOR) concept/constraint trade-offs, and support system structure. A variety of iterations and the trade-offs are possible with impact on the full range of ATE concepts. This trade-off of alternative concepts is a factor in the definition of ATE alternatives.

2.5.2.3 Define ATE Alternatives

For each alternative maintenance concept there may be more than one test equipment alternative. The scope of ATE alternatives is greater during the conceptual phase than it is at later development phases. Following are the steps taken in the definition of alternatives.

a. Propose Generic ATE Types Generic ATE types are proposed which are compatible with each maintenance concept under study as a first step in the selection process. Possible generic ATE options for a system can be made up from one or a combination of the following:

- Built-In Test (BIT)
- Built-In Test Equipment (BITE)
- Other on-line test systems
- Off-line test systems

b. Identify On-Line Test Requirements Prime system and mission needs will have to be analyzed to determine the need for on-line monitoring. In general, from an operational and maintenance viewpoint, on-line monitoring (or testing) is the most desirable mode of operation. The trade-offs involved are cost, technical impact on the design, and the operational requirements for the mission.

c. Identify the Degree of Off-line Test Requirements Many of the selection considerations for on-line test requirements are also applicable to off-line testing. The degree of off-line testing will largely depend on decisions regarding specific maintenance levels and locations (i.e., organizational, intermediate and depot).

2.5.2.4 Select Best ATE Alternative

At the conceptual level of development the ATE alternatives can only be matched with the degree of detail available on the prime hardware, its cost estimate, and the technical definition of detail of the hardware alternatives. It is quite likely that several possible acceptable alternative ATE concepts will still exist after the end of the concept phase. Further refinement of the ATE optimization process should take place during later stages in the system development such as during Advanced Development and Full Scale Development.

2.5.2.5 Select ILS Concept

Selection of the maintenance and ILS concept will determine the ATE concept selection.

2.5.2.6 Define Support Concept

As a result of the above procedures, the ILS concept and ATE concept have been selected. From these a support concept can be defined which will provide a clear understanding for both the ILS and the ATE personnel.

## 2.6 Output Documentation

There are several documents which result from the conceptual phase of development. These are listed here in order to maintain the frame of reference for the cognizant ATE specialist to relate his ATE procedure to other ILS and prime hardware development actions. The following documents (see Figure 1-1) are outputs of the conceptual phase:

a. DP (Development Proposal)
b. PMP (Program Master Plan)
c. APP (Advanced Procurement Plan)
d. DCP (Development Concept Paper)

The DP documents the decisions made on the selection of ATE, and is therefore the most relevant piece of output documentation.

## 3.0 ADVANCED DEVELOPMENT PHASE

In the advanced development or validation phase, continuation of the prime hardware development takes place. Advanced development activities for the prime hardware support system and ATE all proceed in parallel. Support, ILS, maintenance planning, LSA and prime hardware design actions take place as an integrated process and tradeoffs are made between them to produce an Advanced Development Model (ADM) and support system. The material covered in this section is keyed to Figure 1-1. It is germane to note that the advanced development phase represents the transition from the high risk to low risk area of development.

### 3.1 Objectives

There are five main objectives for the advanced development phase listed in Figure 1-1 which highlight the goals of this phase of development. Each of these apply to the selection of ATE as well as the remainder of the prime system or platform development. The item which is significant to the ATE objectives is the establishment of firm and realistic performance specifications, including technical interfaces. It is important that performance specifications and hardware interfaces be established for the ATE and all prime system/platform areas which have any impact on the ATE.

### 3.2 Principal Efforts

Four main areas of activities are listed in Figure 1-1 for the principal efforts during the advanced development phase. In each of the areas listed in the development flow chart the activity followed for the prime hardware also pertains to the ATE and support system. Prototype hardware development of the prime system as well as the ATE should be accomplished. Further refinement of performance specifications, and validation of conceptual studies which cover the ATE/BIT and prime hardware should be made. A preliminary engineering design for the total system/platform should result from the advanced development phase efforts. One of the main efforts is to reduce the degree of risk associated with both the ATE and prime hardware development.

### 3.3 Logistic Support Factors

There are two important logistic support factors which should be addressed during the advanced development phase. Continuing examination and evaluation of support alternatives, and examination of special problems of logistic requirements are the two factors which should be considered. These efforts are a continuation of the effort that was started during the conceptual stage of development.

### 3.4 Logistic Support Design Process

In the corresponding section of Figure 1-1 the logistic support design process is outlined in the block flow chart/diagram format. It is indicated in the diagram that this is a straight flow process (one way) leading through to the development of the ADM. Many of the functions are interactive within their own process and with other functions. For the sake of clarity, the feedback paths are not shown. As an example of the iterative or interactive

nature of a function, consider the Support System Definition function block. In the process of performing the Support System Definition function support system alternatives are balanced against factors such as support facility locations and transportation requirements. LOR and other analyses are made which are optimizing processes (cost is the main optimization factor). The results of these intra-function analyses are then balanced with other external functions to achieve a total optimized system. For example, in the LOR process it could be possible to determine the lowest cost maintenance/repair system for prime hardware with the requirement for a maintenance depot(s) that does not exist. Examination of the external world would reveal that no suitable depot(s) exist and the optimum LOR system could call for the establishment of depots at a great initial outlay of construction and other high startup funds.

## 3.5 ATE Selection Process

### 3.5.1 General

Postulation of ATE alternatives and selection of the "best" or optimum approach is the central theme of ATE selection during the advanced development phase. This process involves the two categories outlined in Figure 1-1 as follows:

a. On-Line ATE (includes BIT/BITE)

b. Off-Line ATE

Each of these functions is discussed in the following paragraphs.

### 3.5.2 Selection Procedure

In the conceptual phase, as outlined in Section 2, the ATE concept (or several equal concepts) will be developed. From this ATE concept (or concepts) alternative approaches will be determined, examined, and a selection of the best alternative made. Alternative systems are matched with the associated proposed support approach, and the selected system will combine the best ATE alternative with it.

#### 3.5.2.1 On-Line ATE

a. Research. Appropriate data banks and literature searches should be made to identify possible testing concepts and techniques. This is a difficult area to catalog and index, especially for BIT/BITE. The SETE data bank listed in Section 7, is available for searches of this type.

b. Analysis. Design approaches identified during the research procedure that were applied to similar systems or platforms should be analyzed for their applicability to the prime system being developed. The term "design approach" is more important to the on-line test selection/design because BIT/BITE must be inherently designed into the prime hardware rather than selecting it off-the-shelf. It is expected that techniques used for the same class of platforms

should be transferable to new platforms and its associated support electronics. Identification of a computer/simulation design aid, such as the NORDEN BITE Model, cited in Section 7, serve to help formalize the BIT/BITE design process and optimize results.

c. Selection of Best Approach. From the background research and analysis, the "best approach" can be selected after applying the total system life cycle cost; considering the effect on the platform or system operational readiness; and technical risk and schedule. The tools listed in Section 7, can aid in this evaluation. One of the prime objectives of the advanced development phase are to reduce the technical risks involved in system development.

d. Design. Once the best on-line test approach has been selected with associated support design tools, the BIT/BITE can be designed into the prime system or platform.

3.5.2.2 Off-Line ATE

In the case of off-line ATE selection, the process lends itself to the identification of specific off-the-shelf ATE or ATE "building blocks". Following are the events/actions which should take place to select off-line ATE.

a. Search. A search of ATE data banks and literature should be made to match Unit Under Test (UUT) requirements with available inventory and other acceptable off-line ATE. Data banks are particularly well suited to the matching of off-line ATE to UUT requirements. The ATE data bank (Avionics Systems Test Equipment Comparator, ASTEC) at NAEC can provide a very accurate (on a pin by pin basis) match between the UUT and ATE in their data bank. In addition, abbreviated summary data on the ATE is also available to users. ASTEC will also file the UUT data as part of its data bank so that future runs can be made against the UUTs. At SAALC (operational 2nd quarter FY 75) their ATE data bank will match UUT requirements against ATE and ATE building blocks. Summary data requirement inputs are described for each UUT to be screened against the ATE in the SAALC data bank. Use of these data banks can be identified through the SYSCOM ATE contacts or ATEMAT/TETSO.

After the data bank search and other research has taken place, the results can be analyzed and alternatives can be identified. Iterations in this process can take place if insufficient data is accumulated during the first pass.

b. Identify Alternatives. When the data banks have been searched and other research and analysis has been completed, alternative off-line ATE can be identified, and also alternative approaches can be determined. Alternative ATE (or building blocks) can be identified from existing inventory assets, or determined to be available off-the-shelf. When the existing ATE capability does not meet the needs for the UUT test capability, modification to the existing ATE can be considered as an alternative. This decision point can be reached when the search of the data banks and literature does not reveal any ATE which meets a high percentage of the UUT test requirements, but shows a 60 to 80 percent coverage. A percentage of UUT test capability is one of the automated data

bank search byproducts. In the event that none of the above approaches yield a good solution, the final alternative is development of new ATE. This is the least desirable alternative due to long lead times and development costs. But if new ATE must be developed then the advanced development phase is the point in time to start (not the production phase where it often happens).

c. Evaluation of Alternatives. Alternatives should be weighed against life cycle costs for the total system. Each alternative should also be evaluated in reference to the effect upon the prime system or platforms operational readiness. Another factor which encompasses all types of ATE is performance. Performance takes into account, probability of failure detection, fault isolation level (within a specified number of modules), speed, and operator usability (consideration of human factors). Reliability, availability, and logistic support of the ATE itself are important factors to be taken into account in resolving the selection of alternatives. Utilization factors (growth potential, installation location, and excess available capacity) should be considered in selecting from off-line ATE alternatives. A number of tools and aids are described in Section 7 to assist in these evaluations.

In selecting alternatives to meet the constraints mentioned above, quite often the most important one is the development delivery schedule. It may be required that ATE alternatives may be selected so that the schedule can be met. Where a far superior approach has to be abandoned in favor to one of lesser acceptability because of schedule requirements, it should be reviewed thoroughly to determine if the schedule can stand this slippage.

## 3.6 Output Documentation

At the completion of the advanced development phase, the documents listed in Figure 1-1 could result. Only the new (different from conceptual phase) documents are discussed below.

a. Preliminary ILS Plan. At the conclusion of the advanced development, an ILS Plan should exist. It will serve as the basis for the ILS planning for all following phases.

b. FSD Specification. The results of the advanced development phase and evaluation of the ADM should include a Full Scale Development (FSD) system specification including the specification for the ATE.

The initial LSAR will be prepared. This documents the Logistic Support Analysis, including the trade-offs relevant to ATE selection.

## 4.0 FULL SCALE DEVELOPMENT PHASE

During the full scale development phase, the system/platform requirement and the threat is reaffirmed; for prime hardware and ATE, cost of ownership is verified, practicality of the engineering design is established, production and logistics problems are identified and considered (solved), technical risks are resolved, operational suitability is determined through test and evaluation, and a realistic plan for production is developed. All of the descriptive material presented in section 4 is keyed to the full scale development time phasing in Figure 1-1. This is the last chance to resolve all the known areas of risk associated with both the prime equipment and ATE prior to the production phase.

### 4.1 Objectives

The single major objective for the full scale development phase is to produce a supportable prime hardware model, and ATE as a precondition to production for inventory or operational deployment. A detailed system design, complete specifications, and associated support documents are also central objectives.

### 4.2 Principal Efforts

Under full scale development in Figure 1-1, there are six main efforts outlined. A continuing assessment of risk is required to surface technical and engineering problems requiring study and resolution. Development milestones, and a management system to track them, should be established to meet the objective. All problems determined during the validation/advanced development phase should be solved or the risks reduced to an acceptable level. All data requirements basic to the hardware design disclosure package, should be verified and deficiencies corrected. All logistic support requirements should be identified, and a formal logistic support system should be designed early in the full scale development phase. Finally, completion of the design of both the prime hardware and ATE should take place through the full scale development efforts.

### 4.3 Logistic Support Factors

In the full scale development phase, a formal structured ILS Plan (based on preliminary ILS Plan) should be developed. This is the plan which will be used to support the prime system/platform during its operational phase. It will also outline the events and actions which must take place during the production phase to support the operational system (including ATE). In addition to the ILS plan, the complete logistic support program should be reviewed for adequacy to support the prime equipment/platform. ATE should be considered in the formal logistic support program from both the standpoint of support to the prime hardware and support of the ATE system.

### 4.4 Logistic Support Design Process

For full scale development, the logistic support design process involves less functional activities than the advanced development design process. This can be gleaned from the section covering the subject in Figure 1-1. Significant functions which are implemented are--the final prime hardware design,

support system design and user test/evaluation of the full scale development model (FSDM). In the FSDM evaluation process, the ATE and other support factors will also be evaluated. The feedback from this evaluation will provide engineering change and design information which can be inputs to the production specifications for the ATE and prime equipment. In the logistics support requirements identification area, the detailed maintenance plan will be completed, LOR will be optimized, support equipment (ATE) requirements, costs, and test design will be completed.

## 4.5 ATE Selection Process

### 4.5.1 General

Selection procedures for both on-line ATE and off-line ATE during full scale development is a process of evaluation, reevaluation and assessment of the final selection. Most of the ATE effort during full scale development involves the design and development aspects with very little emphasis on the selection process.

### 4.5.2 Selection Procedure

Heavy selection activity could take place during full scale development if the advanced development phase is skipped or abbreviated. In that situation some of the selection activity will be covered in the same way as outlined in paragraph 3.5.2. The result will be a compression of both advanced development and full scale development procedures into a single phase. This type of program phasing should only be taken when many of the unknowns are minimal and risk factors are concomitantly low. The tools and aids described in section 7 are again available and applicable during FSD.

#### 4.5.2.1 On-Line ATE (BIT/BITE)

Following are the actions which should take place regarding on-line ATE:

a. Reevaluation and Redesign. This includes considering the BIT/BITE design that was completed during the advanced development phase and refining it from the ADM test and evaluation results. This selection activity will involve the selection of the optimum features for the FSDM BIT/BITE design and incorporating the desired features into the FSDM.

b. Develop BIT/BITE. From the design that evolved from the reevaluation, redesign, and refinement process BIT/BITE will be built into the FSDM for the prime system/platform. As part of the selection process, this development of a FSDM, with the inherent BIT/BITE built into it, will provide an evaluation tool for the integrated system/platform. The advanced development phase will provide the last reasonable point where this integrated BIT/BITE design can be implemented and evaluated.

c. Technical Evaluation/Operational Evaluation. As a subset of the prime system/platform evaluation, the ATE should also be evaluated in the process. This is very significant in the case of BIT/BITE since it cannot be evaluated without the benefit of the prime hardware being in a fully developed status.

For off-line ATE it is possible to perform a successful evaluation with the UUT's to be processed by the ATE. In the on-line ATE situation only after the BIT/BITE has been integrated into the prime equipment, can it be evaluated. The technical and operational evaluations will identify the merits of the FSDM ATE as well as the weaknesses. This evaluation should provide sufficient information to assess the ATE for suitability to go into production and deployment phases.

d. Assessment. When the technical and operational phases have been completed, then the ATE selection can be assessed. This assessment can be made as a measure of the suitability of the ATE selected design approach against its technical/operational evaluation results. The assessment process can be quantized in terms of the percentage of operational and technical objectives which were met by the FSDM. Other assessment approaches could involve how well faults were isolated and the meeting of MTTR specifications (or bettering the requirements). Since the scope of the BIT/BITE is fairly well committed at this stage of development, it is not easy to measurably impact its performance, if the negative aspects of the assessment are unacceptable. An added support technique could be considered; if for example, fault isolation to a single individual module is not attainable, off-line screening ATE could be added to the development program to resolve ambiguities between modules.

4.5.2.2 Off-Line ATE

Selection and evaluation of off-line ATE follows the steps outlined in Figure 1-1 and parallels the on-line case with the exception that there is more emphasis on software.

a. Reevaluation and Development/Procurement. In light of the full scale development operation, the requirements for the off-line ATE should be reevaluated and modified accordingly. The experience from the ADM and FSDM evaluations should provide a strong input to the requirements reevaluation. After reaffirmation and updating of the requirement, the off-line ATE can be developed or procured. The selection procedure is identical to that outlined under section 3 (3.5.2.2) and should be followed again. In addition to the ATE hardware, software (operating system/executive) must also be selected, developed and procured. Test programs must be developed.

b. Evaluate Programming Aids. Support software to assist in the generation of test patterns, and test programs should be evaluated against the test program requirements. For complex digital UUT's (over 50 IC's) it becomes difficult to generate comprehensive accurate test patterns/programs through mannual techniques. An automatic test pattern/program generator such as D-LASAR (Digitest version-Logic Stimulus and Response) should be considered for complex digital logic.

c. Technical/Operational Evaluation. In support of the FSDM evaluation, the off-line ATE should be evaluated. As stated previously, off-line ATE can be evaluated as soon as the UUT's are available. The total prime system FSDM, need not be fabricated in a fully operational test bed in order for evaluation to proceed. In fact, it is recommended that at the onset of availability of UUT's

that the off-line ATE technical evaluation start. Operational evaluation may follow. If the off-line ATE has been scheduled for an intermediate or depot type support plan, then it will be evaluated separately from the same physical proximity of the prime system/platform.

d. Assessment. An assessment of the off-line ATE selection should be performed to establish its adequacy to test the specified UUT's. This assessment can be in terms of meeting the MTTR for the prime system and the MTTR for the UUT's. The number of specified UUT's to be tested, and the number of UUT's which can be tested by the FSDM off-line ATE can also provide a measure for assessment of the selection. Feedback of shortfalls and deficiencies can provide an input to ECP (Engineering Change Proposal) action to correct the situation in the FSDM equipment or the production specifications can be the correction vehicle.

## 4.6 OUTPUT DOCUMENTATION

Full scale development activities will be concluded with the primary end product being a completed detailed design, Final ILS Plan, and Production Specification. Other germane documents are outlined in Figure 1-1, and are the same which applied to the advanced development stage.

## 5.0 PRODUCTION PHASE

Culmination of all of the results of the post development phase takes place during production of the prime system/platform, including on/offline ATE. Minimal ATE selection activity is expected to take place during this phase with the emphasis placed upon production and procurement. Much (if not all) of the risk should have been resolved by this time. The operational suitability of the prime system/platform should have been established, and a firm plan for the production/procurement should exist.

### 5.1 OBJECTIVES

A succinct statement of the two main objectives of the production phase is outlined in Figure 1-1. These objectives involve production/construction of hardware which would meet all the requirements, whether those originally specified, or derived through the development process. Risks should have been eliminated, and the production model (ATE included) should be a result of the hardware/software testing and redesign process, with appropriate tradeoffs. The resultant equipment/system should be available, reliable and supportable to meet its mission requirements for the duration of its life cycle.

### 5.2 PRINCIPAL EFFORTS

There are two principal areas of effort (indicated in Figure 1-1) that are planned in the production phase. Production of the prime system or platform (including the support of ATE) is the main thrust of the production phase. For some areas of activity, there is an overlap effort for items not completed during the full scale development phase. These overlap areas are due to the existence of long lead time production items and the need to complete fragments of the full scale development process. Overlap from the full scale development efforts are possible due to evaluation of the FSDM and its spinoff activities.

### 5.3 LOGISTIC SUPPORT FACTORS

Five logistic support factors are covered in Figure 1-1 for the production phase. A validated or completed LSAR should result from the completion of the production phase and it will also be the primary output documentation. Timely delivery of logistic support resources, including the ATE, is an important logistic support factor which should be monitored. Any variation in the delivery schedule for the support resources should be examined to determine its impact on the prime hardware delivery schedule. If the total hardware schedule is impacted by any slipped support milestones, the schedule requirements should be evaluated to establish if the slippage is allowable. In the event that the total system/platform cannot stand the slippage, then the logistic support resources delivery should be realigned to satisfy the prime equipment.

### 5.4 LOGISTIC SUPPORT DESIGN PROCESS

For the production phase, the five inputs to the analysis and tradeoff studies leading to the fully supported system/platform, are outlined in Figure 1-1. These input functions are the end product of development analyses which have

taken place through the total development process. Their relationship to the total system/platform development picture is that they are the refined analyses of the past phases which have been "fine tuned" to meet the requirements of the production phase. If this is not the case, then the logistic support design functions have not been adequately addressed during prior development phases!

## 5.5 ATE Selection Process

### 5.5.1 General

Selection procedures during the production phase should be minimal for on-line ATE and at various levels for off-line ATE. It is not likely that a system should reach the production phase of development where the BIT/BITE has not been almost completely selected, but it is possible to have a heavy off-line selection role. A candidate off-line ATE selection situation could occur when an initial decision to use off-line ATE is made during early development stages, and the decision is left in a generic form. That is, the ATE selection process was truncated at a level where off-the-shelf, off-line ATE was selected to perform the ATE support function, and procurement action withheld until the production phase.

### 5.5.2 Selection Procedure

#### 5.5.2.1 On-Line ATE

As indicated above, selection procedures for BIT/BITE should be relegated to selecting the design that was proven in the FSDM. This design should be incorporated into the pre-production model (PPM) and subjected to the factory acceptance test. An assessment of the ATE system/design should be made after the fabrication and test of the PPM.

#### 5.5.2.2 Off-Line ATE

In contrast to the minimal on-line production phase selection procedures, there can be possible heavy selection activity for off-line ATE. These selection procedure activities involve the following:

a. Procurement. ATE should be procured to meet the production performance specifications developed during the full scale development phase. There is a two way path possible here depending upon the contractual situation that existed for the production of the system/platform. One possibility is that the prime production contractor has also had full scale development contract and the off-line ATE would be expected to be the same as the FSDM ATE. The other alternative is that the off-line ATE is to be selected by a new prime contractor for the production phase. When this situation occurs, the ATE selection can be subjected to "open" procurement policy even though past development efforts made a "hard" selection. To guard against getting any surprises during the production/procurement phase, the procurement of new ATE should be based on the firm specifications developed from FSDM evaluation. These specifications should be in sufficient detail that all of the functions and capabilities determined to be of value in the FSDM ATE are procured during the production phase. Selection activity should be limited to evaluation of ATE proposals to meet the specifications.

b. Acceptance Tests. Two actions should take place at this point in the production phase; acceptance testing of the pre-production model and development of the TPS (test program sets) for the prime equipment UUT's. The results of the acceptance tests could support the selection and assessment process. TPS development should be done in parallel to assure timely delivery of the test programs concurrently with ATE availability. This is possible for off-line ATE since the UUT's are usually modules that are available during construction of the prime hardware and it is not necessary to wait until completion of the total system to start TPS development.

c. Assessment. There are several sources of information during the production phase which can provide a basis for assessment of the off-line ATE selection. Feedback from the evaluation of proposals, acceptance testing of pre-production model ATE, production line models, and the success of executing test programs on the ATE can be used to assess the quality of the ATE selection. Assessment parameters can include the speed of operation of the ATE, how well it supports the MTTR requirements, and the percentage of required UUT's that can be tested. Deficiencies from the required capabilities which are not due to lack of well defined specifications should be corrected by the contractor. If the lack of performance is due to poor definition of the requirement or specification, then additional funding/contractual action is necessary.

## 6.0 DEPLOYMENT PHASE

### 6.1 General

In the normal course of events, there should be no ATE selection functions after the production phase has been completed. Certainly, there should be no possible on-line BIT/BITE selection activity after the full scale development phase has been completed. It is quite possible that the selection of off-line ATE could take place in the deployment/operational phase to support depot enhancements. There are situations where ATE selections may be necessary due to shifts in operational forces or support concepts. If a depot is set up or expanded to respond to such operational situations, the depots (or IMA's) may require additional ATE to perform new mission requirements. The selection process is the same as those used for the earlier development phases except that the obvious tradeoffs would favor off-the-shelf ATE or items available in the Navy inventory.

### 6.2 Principal Efforts

Once a system/platform is deployed and operational, the main effort is to keep it fully logistically supported to a level where it can meet the mission requirements. Depot and IMA reconfigurations and upgrade actions also entail a significant effort during the deployment phase. Additional test programs (TPS) are also written to support new UUT's/modules (includes design changes which affect TPS execution) in the deployment/operational phase. Modernization programs (Fleet Modernization Program) can account for some ATE selection effort when both the platform and the support system are modernized. It would be expected that the bulk of the ATE selection effort would involve off-line ATE rather than on-line BIT/BITE.

## 7.0 TOOLS, AIDS AND DOCUMENTATION

### 7.1 General

Selection of ATE and the counterpart life cycle costing and support system tradeoffs can be simplified through the judicious use of available tools, aids, and documentation. The tools and aids section, refers to computer implemented models, data bank sources, and guides that would assist in the selection of ATE during various development phases. Documentation and references consist of applicable DID's (Data Item Descriptions) and existing documentation applicable for selection of ATE.

### 7.2 Tools & Aids for Use in the ATE Selection Process

In Table 7-1, the most applicable guides, models, and data banks are listed by title, function, applicable life cycle phase, reference (source or authority) and additional sources of information. The life cycle column applies to the development or acquisition phase outlined in Figure 1-1, and described in sections 2 through 6 of this document. These tools were identified in 1974 and were considered most applicable to the ATE selection process at the time, and are not intended as a compendium of all possible sources of aid. If other tools or selection aids are considered by the cognizant ATE selection specialists as being more suitable, then they should be used instead of those presented here. It is requested that any other models or aids which are found to be of value in the ATE selection process, and the related support areas, should be forwarded to the NAVMAT Office (MAT 03T) responsible for this document. When sufficient updating information is available, then the following charts will be updated.

Data Item Descriptions (DID's) are listed in Table 7-2 as a time saving measure to assist acquisition managers in preparation of contract data requirement lists (DD 1423's) for ATE. This list of DID's is the result of a screening of all the DID's on file at NELC (Code 4100) in mid 1974. More suitable DID's may be substituted or added as time progresses and others are available and determined to be applicable.

Additional information on references in Tables 7-1 and 7-2, may be obtained from the Test Equipment Technical Support Office, NELC, Code 4050.

TABLE 7-1

TOOLS & AIDS FOR USE IN THE ATE SELECTION PROCESS

| TITLE | TYPE FUNCTION | APPLICABLE LIFE CYCLE PHASE | REFERENCES | SOURCES OF ADDITIONAL INFO |
|---|---|---|---|---|
| DATA BANKS | | | | |
| Secretariat, Electronic Test Equipment (Project SETE) | Data Bank-Technical info on all types of test equipment | Conceptual<br>Advanced Development<br>Full Scale Development | NAVMATINST 5200.35<br>MIL-STD 1556<br>NAVMAT Notice 5200 | Project SETE, Government-Industry Data Exchange Program Code 862<br>Fleet Missile Systems & Evaluation Group Corona, CA<br>AV: 933-4351 |
| Avionic Systems Test Equipment Comparator (ASTEC) | Data Bank-Comparing & matching electronic UUT's (pin by pin) with off-line tester capabilities | Advanced Development<br>Full Scale Development | --- | Commanding Officer<br>Naval Air Engineering Center, Code SE-31<br>Philadelphia, PA<br>AV: 443-4531 |
| ATE Data Bank | Data Bank-Stores off-line ATE characteristics (includes ATE building block Information) | Advanced Development<br>Full Scale Development | Automatic Test Equipment Acquisition Planning Guide (January 31, 1974) | Head Quarters San Antonio Air Logistics Command, Kelly Air Force Base, TX<br>AV: 6127 |
| MODELS | | | | |
| 1. BIT/BITE/On-Line | | | | |
| Built-In Test Evaluation Model (BITEM) | Model-Evaluates specific BITE configurations | Advanced Development<br>Full Scale Development | Final report RCA contract No. N00123-73-C-1326 | Naval Electronics Laboratory Center Code 4050 San Diego, CA AV:933-6173 |
| Determination of BIT Effectiveness Utilizing Simulation Language & General Purpose Computer | Model-Predicts BIT Effectiveness for Radar & other applications | Advanced Development<br>Full Scale Development | Norden Report 3676 R 1101 | Norden Division of United Aircraft |

| TITLE | TYPE OF FUNCTION | APPLICABLE LIFE CYCLE PHASE | REFERENCES | SOURCES OF ADDITIONAL INFO |
|---|---|---|---|---|
| An Effectiveness Study for System Formulation of Centralized Automatic Test System | Model-Evaluates the effectiveness of on-line centralized ATE | Advanced Development | DDC (AD 844872L) | NELC Code 4050<br>San Diego, CA<br>AV:933-6173 |
| Technique for Evaluating Avionics Built-In Test | Model-Methods for evaluating the effectiveness of BIT | Advanced Development<br>Full Scale Development | Contract No. N00019-71-C-0312 | Naval Air Systems Command Washington, D.C. |
| A Model for Analysis of Value & Risk of a Built-In Test Equipment System | Model-Measures the effectiveness for built-in test equipment | Advanced Development<br>Full Scale Development | LD29196 | In-house study<br>Capt. Joseph Krutulis USA |
| **2. Level of Repair** | | | | |
| Level of Repair | Model-Decision to repair or discard assemblies at each maintenance level | Conceptual<br>Advanced Development, Full Scale Development | MIL-STD 1390 | Naval Weapons Engineering Support Activity Code 83<br>Washington Navy Yard<br>Washington, D.C.<br>AV: 288-4084 |
| Cost & Operational Analysis of Maintenance Policies (COAMP) | Model-Level of Repair determines life cycle logistics cost for different maintenance alternatives. Model simultaneously addresses four indenture levels | Advanced Development<br>Full Scale Production Development | ---- | Naval Air Development Center Code SAED/SR<br>Johnsville<br>Warminster, PA<br>(UNABLE TO OBTAIN MODEL FROM NADC) |
| Level of Repair Analysis (LORA) | Model-Similar to COAMP Equations modified to conform to AR-60 | Advanced Development<br>Full Scale Production Develop. | NADC Report No. SD 7134 | Naval Air Development Center Code SAED/SDD<br>Warminster, PA<br>(UNABLE TO OBTAIN MODEL FROM NADC) |

| TITLE | TYPE OF FUNCTION | APPLICABLE LIFE CYCLE PHASE | REFERENCES | SOURCES OF ADDITIONAL INFORMATION |
|---|---|---|---|---|
| Hughes Modified Optimum Repair Level Analysis | Model-Level of Repair Model. Determines life cycle logistics cost of different maintenance alternatives. Addresses one indenture level | Advanced Development<br>Full Scale Development | NAVAIR Contract N00019-71-C-0187/ T00030<br>Hughes reference No. C6615 | HAC Canoga Park, CA (MODEL USED TO PERFORM LOR ON AIM-54A PHOENIX MISSILE & ALL-UP-ROUND TESTER) |
| Level of Repair Analytical techniques for Ground Support Equipment | Model- Level of Repair Model Similar to COAMP & LORA Model modified to accomodate GSE | Advanced Development<br>Full Scale Development | No formal documentation | Naval Air Development Center Code SAED/SDD<br>Warminster, PA |
| **3. Miscellaneous** | | | | |
| System Cost & Operational Resource Evaluation (SCORE) | Model-Life Cycle Cost Predicts cost growth of new system based upon historical data from previous systems | Advanced Development<br>Full Scale Production<br>Development | NADC Report No. SD 6925 | Naval Air Development Center Code SAED/SDD<br>Johnsville<br>Warminster, PA |
| Concept Formulation Study for Automatic Inspection, Diagnostic & Prognostic Systems | Model-Description of cost & effectiveness models | Advanced Development<br>Full Scale Development | Contract No. DAAJ01-71-C-0503 | Northrup Corp.<br>Electronics Division |
| Generalized Effectiveness Methodology (GEM) | Model-R,M, & A design trade-offs in relation to time | Conceptual<br>Advanced Development | NAVMAT P-3920 | Naval Ships Engineering Center, Code 6012C<br>Hyattsville, MD<br>AV: 296-1551 or<br>Naval Electronics Laboratory Center<br>Code 4100 San Diego, CA<br>AV: 933-6386 |
| VAST Intermediate Maintenance Activity Effectiveness by Workload Simulation (VIEWS I) | Model-Simulation of VAST workload vs. quene lengths | Advanced Development<br>Full Scale Development<br>Production | ---- | Naval Air Development Center Code SAED/SDD<br>Johnsville<br>Warminster, PA |

| TITLE | TYPE OF FUNCTION | APPLICABLE LIFE CYCLE PHASE | REFERENCES | SOURCES OF ADDITIONAL INFORMATION |
|---|---|---|---|---|
| VIEWS II | Model-Simulation of workshop; in conjunction with aircraft operations, maintenance & supply support | Advanced Development<br>Full Scale Development<br>Production | CNA Report<br>07 102400.05<br>of 19 July 1973 | Naval Air Development Center Code SAED/SDD Johnsville<br>Warminster, PA &<br>Center for Naval Analyses Arlington, VA |
| GUIDES | | | | |
| ILS Program Requirements | Guidance for preparation of ILS Plans & performing LSA's | ALL | MIL-STD-1388-1<br>MIL-STD-1369 (EC)<br>MIL-M-24365A (Ships)<br>AR-30 | NAVWESA<br>NAVELEX 0517<br>NAVSEC<br>NAVAIR |
| Test requirements Documentation | Guide-Documents test requirements. Input for ATE Selection | Advanced Development<br>Full Scale Development | MIL-STD 1345<br>MIL-STD 1519 | NAVELEX<br>Wright Paterson Air Force Base, Ohio |
| Trade Studies (Selection of Avionics Test Support Systems) | Guide-Criteria for conducting trade studies (optimized cost- effectiveness support) for avionics testers | Conceptual<br>Advanced Development<br>Full Scale Development | MIL-STD 1513 | Aeronautical Systems Division ENZSM, Wright Patterson Air Force Base, Ohio |
| Life Cycle Costing Procurement Guide | Guide-Guidelines for applying the life cycle costing concept | Conceptual<br>Advanced Development | LCC-1 | Naval Material Command MAT 042<br>Washington, D.C. |
| Casebook Life Cycle Costing in Equipment Procurement | Guide-Illustrative example of Life Cycle Costing | Conceptual<br>Advanced Development | LCC-2 | Naval Material Command<br>MAT 042<br>Washington, D.C. |
| Life Cycle Costing Guide for Systems Acquisitions | Guide-Guidelines for applying the life cycle costing concept in system acquisition | Conceptual<br>Advanced Development | LCC-3 | Naval Material Command<br>MAT 042<br>Washington, D.C. |

TABLE 7-2

DID's APPLICABLE TO ATE

| NUMBER | COG. | TITLE |
|---|---|---|
| DI-L-2082/UDI-R-21228 | NAVY | LOR Summary Report |
| DI-L-2083/UDI-R-21229 | NAVY | LOR Station Reports |
| DI-L-2084/UDI-R-21230 | NAVY | LOR Program Plan |
| DI-L-2085/UDI-R-2131 | NAVY | LOR Analysis Repairs |
| DI-S-6171 | ARMY | MEA Data |
| DI-S-6168 | ARMY | MEA Program Plan |
| DI-S-6170 | ARMY | ILS Verification Demonstration & Evaluation Plan |
| DI-L-6138 | NAVY | Integrated Support Plan |
| DI-T-3734 | USAF | Test Requirements Documents |
| UDI-T-22732 | NAVY | Test Point Measurement Parameters & Recommended Support Test Equipment Data |
| UDI-T-22735B | NAVY | Planned, Built In Test Equipment (BITE) Fault Location |

## 8.0 SUMMARY

### 8.1 Conclusions

The most important conclusions to be drawn from this report are:

a. Selection of ATE is an integral part of prime system/platform design.

b. Advanced Development/Validation phase is the most critical phase of the ATE selection process.

c. The selection of ATE is, in most cases, an integral part of the ILS/LSA process.

### 8.2 Follow-On Efforts

There are no plans to issue this document as a NAVMAT guide for selection of ATE. This selection procedure will be incorporated into a variety of existing and new documentation, which will be an integral part of prime hardware acquisition process. For example, the following documents will be prepared or revised to include elements of the ATE selection procedure:

a. A NAVMATINST on ATE data banks and their uses.

b. A Navy ATE acquisition guide.

c. A Navy built-in test design guide.

d. Formats of other applicable documents:

- Development Proposal
- ILS Plans
- LSA R
- MIL-STD-1388
- NAVMATINST 4000.20A
- MIL-STD-1390
- Data Items Descriptions

In addition, the tools and aids cited with be analyzed to ascertain their usefulness, and areas where no aids exist will be identified.

In the meantime, use of this document as a guide to the selection of ATE is encouraged.